Refuge Cooperative Research Program Final Report 2012 Supplement

This supplement is not a stand-alone document, but an addition to the 90-page RCGAM Refuge Cooperative Research Program Final Report.

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RCGAM 2012 Supplement Contents

This supplement provides deliverables that could not be included in the original final report, submitted February 28, 2011. Deliverables, and supplement contents, are listed here:

1. *A functional Decision Tool that can be used by refuges to guide long term RCG control*: the development of the Decision Tool rests on our determination of the effect of broadcast seeding. This effect alters the outcome of the glyphosate application, the transition probabilities associated with several management actions, and the potential stratification of transition probabilities. Once this effect is determined, a manual for overall coordination of data entry, updated Decision Tool use, and the model will be provided.
2. *Long term RCG management recommendations for each refuge:* Consistent with the DOI's policy on adaptive management, we recommend refuges simply follow the updated policies generated by the decision tool. These recommendations will be further refined through the use of the Decision Tool and by interactions with participants.
3. *Recommendations for future AM projects:* Recommendations to FWS regarding the transition to the operational phase of RCGAM have begun in the form of discussions between the Science Team and the Biological Monitoring Team from FWS.
4. *Protocols for data collection suitable for long term monitoring:* Determination of these protocols rests on the effect of broadcast seeding. After completion of the 2011 field season, we can provide long term protocols. These protocols will be developed with participant guidance on the level of effort and intensity that are reasonable within refuge capabilities.
5. *At least two publications in a peer-reviewed journal that describe major results and recommendations from the study:* Several publications have resulted from this work, and one peer reviewed publication has published (see *Publications resulting from this work* below). Other publications are in progress or planned.

I. Functional Decision Tool

A. RCG invaded wet meadows ("Meadows")

1. Model of state and transition

Below, the components of the model of state and transition are described. Excel spreadsheets of the components are included as digital appendices to this report supplement, and the Decision Tool resides in an Access database which is also included as a digital appendix. A User guide is also included in this supplemental report (see *C. User Guide to the Decision Tool*, page 107).

a) State definition

Here we describe the 7 states of the meadow tool and how they are defined in concept and based on the monitoring data. Cover classes of native perennial (NP), reed canary grass (RCG), native annual (NA), and bareground (BG) refer to the following scheme: 0 (not present), 1 (<1%), 2 (1-5%), 3 (>5-25%), 4 (>25-50%), 5 (>50-75%), 6 (>75-100%).

1) NPN: Native perennial non-graminoids. This is a wet meadow dominated by non-graminoid native perennials such as rushes, sedges, and forbs (see section on long term monitoring protocol for assistance on distinguishing graminoids from rushes and sedges). The NPN component is determined from the NP guild data and designating individual species as non-graminoids. If native non-graminoids are the dominant component of the NP guild then the state is NPN. The following are possible cover class combinations that lead to this state NP 6/RCG ≤3; NP 5/ RCG ≤2.

2) NPG: Native perennial grass. This is a wet meadow dominated by native perennial grasses. Grasses are defined as true grasses (graminoids). See section on long term protocol for assistance on distinguishing graminoids from non-graminoids. The NPG component is determined from the NP guild data and designating individual species as graminoids. If native graminoids are the dominant component of the NP guild then the state is NPG. The following are possible cover class combinations that lead to this state NP 6/RCG ≤3; NP 5/ RCG ≤2.

3) NPN/RCG: Non-graminoid native perennial/RCG. This is a nearly wet meadow with non-graminoid native perennials as a large component and the presence of RCG at low levels. The following are cover class combinations that lead to this state: NP 6/RCG 4; NP 5/RCG 4 or 3; NP 4/RCG 2 or 1; and NP 3/RCG 1.

4) NPG/RCG: Native perennial graminoid/RCG. This is a nearly wet meadow with native perennial grasses as a large component and the presence of RCG. The following are possible cover class combinations that lead to this state: NP 6/RCG 4; NP 5/RCG 4 or 3; NP 4/RCG ≤2; and NP 3/RCG 0.

5) BG: Bareground. This state is determined by using the native annual guild. The following cover class combinations lead to a bareground state: NA 3 or less/RCG 2 /NP 0, 1, 2; NA ≤ 2/RCG 1/NP ≤2; RCG 0/NP 0; BG 5/NP 5/other guilds ≤1; BG 6/other guilds ≤1.

6) RCG/NP: RCG/native perennial. This is a nearly RCG meadow with native perennial component. The following cover class combinations lead to this state: RCG 6, 5/NP 4.

7) RCG: RCG. This is an RCG dominated meadow. If RCG has a cover class of 6 or 5 and an NP component less than 3 this is an RCG meadow.

b) Actions

Actions to be included in the Decision Tool were selected based on a demonstrated efficacy in the literature. We limited our list of management actions in order to support the simplicity of the Decision Tool that would facilitate the fastest rate of learning.

1) F: Fusilade (grass-specific herbicide, active ingredient: Fluazifop). Apply in spring only during May/June prior to RCG anthesis.

2) G: Glyphosate (broadspectrum herbicide). Apply in August.

3) G+S: Glyphosate + seeding with wet meadow species. Spot spray in May or August followed by seed in late fall, winter, or early spring. Site preparation (including burning) may precede seeding if necessary.

4) Seeding with wet meadow species alone. Seeding without a prior herbicide application in the same decision cycle. Site preparation (including burning) may precede seeding if necessary.

5) NA: No action.

c) Transition probabilities

We calculated transition probabilities associated with the 7 states and 4 actions listed above based on data collected during the research phase of RCGAM (field seasons 2008-2011). RCG competitive ability is inherently linked to soil nitrogen, and therefore management actions have distinctly different outcomes for different levels of soil nitrogen. As a result, transition probabilities were stratified by nitrogen (NOX-N) level into low (<2 mg/kg) and high (>2mg/kg) classes. Examples of transitions, listed by state and treatment, stratified by nitrogen level are provided in Figure 1.

<u>Pertinent Digital Supplement:</u> Wet meadow utility, transitions and competing models Excel file: transitions tab.

	Nitrogen Class	Prior_ST	Post_ST	G	GG	F	N	S	GS
2	LOW	NPN	NPN	0.2625	0.3	0.8	0.690789	0.690789	0.4125
3	LOW	NPN	NPG	0.0875	0.1	0.05	0.230263	0.230263	0.1375
4	LOW	NPN	NPN/RCG	0.075	0.0375	0.01	0.035526	0.035526	0.1125
5	LOW	NPN	NPG/RCG	0.025	0.0125	0.04	0.011842	0.011842	0.0375
6	LOW	NPN	BARE	0.45	0.55	0.1	0	0	0.25
7	LOW	NPN	RCG/NP	0.075	0	0	0.026316	0.026316	0.05
8	LOW	NPN	RCG	0.025	0	0	0.005263	0.005263	0
9	HIGH	NPN	NPN	0.15	0.15	0.58	0.496988	0.496988	0.1875
10	HIGH	NPN	NPG	0.05	0.05	0.03	0.165663	0.165663	0.0625
11	HIGH	NPN	NPN/RCG	0.0375	0.075	0.01	0.063253	0.063253	0.225
12	HIGH	NPN	NPG/RCG	0.0125	0.025	0.03	0.021084	0.021084	0.075
13	HIGH	NPN	BARE	0.45	0.55	0.2	0.192771	0.192771	0.25
14	HIGH	NPN	RCG/NP	0.15	0.05	0.05	0.012048	0.012048	0.1
15	HIGH	NPN	RCG	0.15	0.1	0.1	0.048193	0.048193	0.1

Figure 1. Example of transition probabilities for reed canary grass management in wet meadows. Nitrogen classes reflect the amount of nitrogen gathered at the management unit. Seven states exist (see state definitions above) for each nitrogen class. The first column is nitrogen class, the second and third columns show the state prior to and after treatment actions, respectively. The following columns are the transitions for glyphosate (G), glyphosate+glyphosate (GG), fusilade (F), no action (NA), seeding (S), and glyphosate+seeding (G+S).

2. **Structural uncertainties to be resolved through decision-making:**

The effectiveness of seeding, either alone or with glyphosate, is the key uncertainty in the wet meadow adaptive management. Because "seeding alone" occurs in bare ground, we represent this uncertainty only in the transition probabilities from bare to all states. The glyphosate plus seeding action could potentially occur in all states so that is represented for all observed states. The competing models were generated using expert opinion that was influenced by the relative transition rates observed in other treatments. Twenty-one competing models were created with model 1 representing a completely ineffective seeding, i.e. seeding is the same as rest, and model 21 represents a completely effective seeding. Models 2-20 were created by scaling the probabilities between models 1 and 21 in equal steps such that model 2 was equal to model 1 plus 1/20th of the difference between models 21 and 1.

3. **Expression of utilities**

We determined utilities based on land manager perspective of possible management outcomes and estimated treatment costs provided by land managers. The utility values are determined with three components: 1) the state an action brings you to, 2) whether the action improved or degraded the habitat, and 3) the cost of actions (Ganon et al. 2012). The highest utility is achieved when the cheapest action yields large improvements that bring you to the most desired state. The lowest utility is achieved when the most expensive action actually causes severe degradation from desired to undesirable states. Examples of utilities, listed by state and treatment, stratified by nitrogen level are provided in Figure 2.

Pertinent Digital Supplement: Wet meadow utility, transitions and competing models Excel file: utilities tab.

	Nitrogen Class	Prior_ST	Post_ST	G	GG	F	N	S	GS
2	LOW	NPN	NPN	0.975	0.95	0.93	1	0.905	0.9
3	LOW	NPN	NPG	0.975	0.95	0.93	1	0.905	0.9
4	LOW	NPN	NPN/RCG	0.575	0.57	0.558	0.6	0.543	0.54
5	LOW	NPN	NPG/RCG	0.575	0.57	0.558	0.6	0.543	0.54
6	LOW	NPN	BARE	0.375	0.38	0.372	0.4	0.362	0.36
7	LOW	NPN	RCG/NP	0.175	0.19	0.186	0.2	0.181	0.18
8	LOW	NPN	RCG	0.075	0.095	0.093	0.1	0.0905	0.09
9	HIGH	NPN	NPN	0.975	0.95	0.93	1	0.905	0.9
10	HIGH	NPN	NPG	0.975	0.95	0.93	1	0.905	0.9
11	HIGH	NPN	NPN/RCG	0.575	0.57	0.558	0.6	0.543	0.54
12	HIGH	NPN	NPG/RCG	0.575	0.57	0.558	0.6	0.543	0.54
13	HIGH	NPN	BARE	0.375	0.38	0.372	0.4	0.362	0.36
14	HIGH	NPN	RCG/NP	0.175	0.19	0.186	0.2	0.181	0.18
15	HIGH	NPN	RCG	0.075	0.095	0.093	0.1	0.0905	0.09

Figure 2. Example of utilities for reed canary grass management in wet meadows. Nitrogen classes reflect the amount of nitrogen gathered at the management unit with seven states (see state definitions above). The first column is the nitrogen class, the second and third columns show the state prior to and after treatment actions. The following columns are the transition probabilities for glyphosate (G), glyphosate+glyphosate (GG), fusilade (F), no action (NA), seeding (S), and glyphosate+seeding (G+S).

4. Algorithm for computation of optimal state-specific decision policy for any arbitrary weighting of uncertain models

For a description of the algorithm, see final report "5. Identify decision structure and Dynamic Optimization" page 12.

5. Algorithm for model weight updating

We use Bayesian Inference to update the weights of each competing model for both the meadow and forest (section I.B.), and to update the probability of a model based on evidence observed. Bayes' law is defined as _____ _____,

where $P(M)$ is the prior probability or our belief in model M. $P(E|M)$ is the likelihood function, which is defined as the probability of observing the evidence E given that M is the true model. $P(E)$ is the total or unconditional probability of observing the evidence, and $P(M|E)$ is the posterior probability, or our belief that M is the true model given the observed evidence.

In the meadow model, we have two actions with competing models – glyphosate plus seeding and seeding alone. Each action has 21 competing models. Since there is uncertainty about which model best reflects the evidence, we used a uniform prior

distribution for each action: — for the glyphosate plus seeding mode weights and — for the seeding model weights. The next component of Bayes' law is the likelihood function. In our case, the likelihood of each observation is defined as the transition probability for the competing model. The denominator of Bayes' law is simply the sum of each models transition probability multiplied by its corresponding prior distribution. For specifics on the forest model see section I.B.5.

As each piece of evidence is observed, Bayes' law can be used to repeatedly update the posterior probability of each model. This is done by using the posterior distribution from the last observation as the prior distribution for the subsequent observation. In principle, model weight updating can be chained together across the collection of plots within management units in a single year. However, in certain instances, model weights can change unrealistically rapidly, especially if the system is not sufficiently characterized by the model set. To address the concern with the meadow models, we apply the same prior distribution to all plots within a single management unit. The resulting posteriors are then averaged and passed to the next set of plots within the next management unit to serve as this unit's prior weights.

6. Lookup of optimal action given the observation of each plot and updated model weights

Once the Bayesian updating is completed, the posterior model weights are used to create probability weighted transition probabilities for each action. These transitions are then used in the Stochastic Dynamic Program as described on page 12 of the final report. The output of the Stochastic Dynamic Program is an optimal policy dictating the recommended action for each state.

Below is the optimal policy for the meadow states, applying equal belief weight to each model. The assignment of equal weight reflects an initial admission of uncertainty about the system and initial presumption that any competing model is equally credible.

Figure 3. Optimal meadow policy using updated model weights *or* equal model weights (equivalent policies generated)

In the case of the meadow model, the policies using the updated model weights or equal model weight are equivalent. This is due to several factors. First, there are 21 competing models. In order to significantly improve our understanding, we require a large number of plots implementing Seeding or Glyphosate plus Seeding. Currently, the data has indicated that seeding is more likely to be effective, but due to the number of competing models and the lack of data, the evidence is weak. Thus, there is no impact in the policy. In other words, any pair of successive models chosen from this set are essentially identical – there's not enough different about them to suggest different optimal actions.

We can investigate the impact of seeding effectiveness on the optimal policy. If we assume that seeding is effective, we see that the policy does change. The policy below was derived assuming that model 21 (most effective seeding model) receives 100% of the weight (and all other competing models receive 0%). We see that it is now optimal to perform seeding in State: Bare, high nitrogen. In addition, it is now optimal to perform glyphosate plus seeding in states RCG/NP, low nitrogen and RCG, low nitrogen. Therefore, as we learn more about the effectiveness of seeding, we can expect our optimal policy to change to reflect this improved understanding.

Figure 4. Optimal policy based on 100% effectiveness of seeding (i.e. weight = 1 on seeding and GS Model 21)

7. Database to record and summarize actions and vegetation

An Access database was created and a description and user guide is provided in *C User Guide to the Decision Tool* on page 107.

Pertinent Digital Supplement: Microsoft Access Database

B. RCG invaded floodplain forests ("Forests")

1. Model of state and transition

Below, the components of the model of state and transition are described. Excel spreadsheets of the components are included as digital appendices to this report supplement, and the Decision Tool resides in an Access database which is also included as a digital appendix. A User guide is also included in this supplemental report (see *C. User Guide to the Decision Tool*, page 107).

a) State definition

Here we describe the 7 states of the forest tool and how they are defined in concept and based on the monitoring data. Cover classes refer to the following scheme: 0 (not present), 1 (<1%), 2 (1-5%), 3 (>5-25%), 4 (>25-50%), 5 (>50-75%), 6 (>75-100%).

1) A (for ABSENT): No RCG and no trees
RCG cover class 0 and no trees of any size

2) R (RCG with trees absent): RCG present and no trees -
RCG cover class 1, 2, 3 and no trees of any size

3) AT (trees mainly): Little RCG and trees susceptible to Glyphosate -
RCG cover class 0 and 1 or more seedlings or saplings <100 cm

4) RAT (mix of everything): RCG not abundant and trees susceptible to Glyphosate
RCG cover class 1, 2, 3, and 1 or more seedlings or saplings <100 cm

5) RT (RCG with some trees): RCG abundant and trees susceptible to Glyphosate
RCG cover class 4, 5, 6 and 1 or more seedlings or saplings <100 cm

6) TA (trees and RCG is absent): No RCG and some trees resistant to Glyphosate
RCG cover class 0 and 1 or more trees >100 cm

7) TR (RCG present and trees resistant to Glyphosate): RCG cover class 1, 2, 3, 4, 5, 6 and 1 or more trees > 100 cm

b) Actions

Actions to be included in the Decision Tool were selected based on a demonstrated efficacy in the literature. We limited our list of management actions in order to support the simplicity of the Decision Tool that would facilitate the fastest rate of learning. For more detail on treatment implementation, see Appendix 4, page 39)

1) G: Glyphosate. Apply in glyphosate in August as a broadcast application.

2) G+S: Glyphosate+seeding tree species. Seed after glyphosate application in the previous August, sow seed in spring or winter.

3) S: Seeding alone. Seeding without a prior herbicide application in the same decision cycle. Site preparation (including burning) may precede seeding if necessary.

4) NA: No action.

c) Transition probabilities

Transition probabilities were stratified by a Close (<25 m) distance class (A, B, and C), and a far (>45 m) distance class (D and E) (i.e., two classes of proximity to forest edge). Examples of transitions, listed by state and treatment, stratified by distance are listed in Figure 5.

Pertinent Digital Supplement: Forest utility, transitions and competing models Excel file: transitions tab

	Distance_	Prior_ST	Post_ST	G_noDistance	G_distance	R_noDist	R_distance	S_ineff_noDistance	S_eff_noDistance	S_ineff_Distance	S_eff_Distance	GS_ineff_noDistance	GS_eff_noDistance	GS_ineff_Distance	GS_eff_Distance
2	CLOSE	A	A	0.387	0.390	0.129	0.178	0.129	0.178	0.178	0.207	0.387	0.430	0.390	0.355
3	CLOSE	A	R	0.155	0.065	0.387	0.221	0.387	0.221	0.221	0.106	0.155	0.001	0.065	0.024
4	CLOSE	R	A	0.079	0.067	0.096	0.082	0.096	0.082	0.082	0.066	0.079	0.064	0.067	0.055
5	CLOSE	R	R	0.463	0.371	0.420	0.334	0.420	0.334	0.334	0.254	0.463	0.377	0.371	0.284
6	CLOSE	AT	A	0.169	0.184	0.096	0.152	0.096	0.152	0.152	0.207	0.169	0.218	0.184	0.186
7	CLOSE	AT	R	0.068	0.033	0.288	0.202	0.288	0.202	0.202	0.122	0.068	0.001	0.033	0.015
8	CLOSE	AT	AT	0.528	0.640	0.141	0.248	0.141	0.248	0.248	0.376	0.528	0.615	0.640	0.718
9	CLOSE	AT	RAT	0.176	0.104	0.226	0.192	0.226	0.192	0.192	0.141	0.176	0.138	0.104	0.056
10	CLOSE	AT	RT	0.035	0.021	0.197	0.168	0.197	0.168	0.168	0.123	0.035	0.006	0.021	0.011
11	CLOSE	AT	T	0.017	0.016	0.013	0.017	0.013	0.017	0.017	0.020	0.017	0.021	0.016	0.014
12	FAR	A	A	0.387	0.384	0.129	0.000	0.129	0.178	0.000	0.154	0.387	0.430	0.384	0.438
13	FAR	A	R	0.155	0.254	0.387	0.570	0.387	0.221	0.570	0.316	0.155	0.001	0.254	0.120
14	FAR	A	AT	0.322	0.191	0.113	0.000	0.113	0.212	0.000	0.110	0.322	0.416	0.191	0.297
15	FAR	A	RAT	0.107	0.138	0.181	0.208	0.181	0.184	0.208	0.206	0.107	0.108	0.138	0.116
16	FAR	A	RT	0.022	0.028	0.158	0.208	0.158	0.160	0.208	0.180	0.022	0.023	0.028	0.023
17	FAR	A	T	0.005	0.002	0.008	0.000	0.008	0.016	0.000	0.006	0.005	0.013	0.002	0.004
18	FAR	A	TR	0.002	0.002	0.023	0.013	0.023	0.029	0.013	0.028	0.002	0.008	0.002	0.002
19	FAR	R	A	0.079	0.091	0.096	0.112	0.096	0.082	0.112	0.099	0.079	0.064	0.091	0.081
20	FAR	R	R	0.463	0.559	0.420	0.512	0.420	0.334	0.512	0.427	0.463	0.377	0.559	0.471
21	FAR	R	AT	0.066	0.048	0.084	0.063	0.084	0.104	0.063	0.082	0.066	0.086	0.048	0.064

Figure 5. Example of transition probabilities for reed canary grass management in floodplain forests. The two distance classes reflect the distance between monitoring stations and the forest edge, and seven states exist for each class (see state definitions above). The first column is the distance class and the second and third columns show the state prior to and after the action. The colored columns represent the transitions given the action that occurred: glyphosate (G), rest or no action (NA), seeding (S), and glyphosate+seeding (GS).

2. Structural uncertainties to be resolved through decision-making

There are two main sources of uncertainty regarding the efficacy of the actions: 1) the effectiveness of manual seeding and 2) the effect of distance to the forest edge on RCG competitive ability. We have estimates for the effect of glyphosate and rest (no action) but not the influence of the distance to forest edge combined with seeding treatments on RCG response and resulting species composition. For the two treatments with seeding (seeding alone or glyphosate plus seed), we have little data with which to derive estimates. Thus, there are two mechanisms 1) seeding efficacy, and 2) effect of distance to edge on RCG competitive ability and species composition, that are intertwined. In combination they generate four hypotheses and four competing models: seeding is 1) ineffective with distance not affecting RCG response and species composition, 2) ineffective with a strong effect of distance, 3) effective with no effect of distance on RCG response and species composition or 4) effective with a strong effect of distance on response and species composition. Glyphosate plus seeding has the same four competing models.

3. Expression of utilities

The utility values are determined with three components: 1) the state an action brings you to, 2) whether the action improved or degraded the habitat, and 3) the cost of actions. The highest utility is achieved when the cheapest action yields large improvements that bring you to the most desired state. The lowest utility is achieved when the most expensive action actually causes severe degradation from desired to undesirable states. Examples of utilities, listed by state and treatment, stratified by distance are provided in Figure 6.

Pertinent Digital Supplement: Forest utility, transitions and competing models Excel file: utilities tab

	Distance Class	Prior State	Posterior State	Rest	Glyphosate	S	GS
2	CLOSE	A	A	0.775	0.750	0.680	0.675
3	CLOSE	A	R	0.325	0.300	0.230	0.225
4	CLOSE	A	AT	0.892	0.867	0.797	0.792
5	CLOSE	A	RAT	0.775	0.750	0.680	0.675
6	CLOSE	A	RT	0.578	0.553	0.483	0.478
7	CLOSE	A	T	1.000	0.975	0.905	0.900
8	CLOSE	A	TR	0.916	0.891	0.821	0.816
9	CLOSE	R	A	0.888	0.863	0.793	0.788
10	CLOSE	R	R	0.550	0.525	0.455	0.450
11	CLOSE	R	AT	0.960	0.935	0.865	0.860
12	CLOSE	R	RAT	0.888	0.863	0.793	0.788
13	CLOSE	R	RT	0.747	0.722	0.652	0.647
14	CLOSE	R	T	1.000	0.975	0.905	0.900
15	CLOSE	R	TR	0.972	0.947	0.877	0.872
16	FAR	A	R	0.325	0.300	0.230	0.225
17	FAR	A	AT	0.892	0.867	0.797	0.792
18	FAR	A	RAT	0.775	0.750	0.680	0.675
19	FAR	A	RT	0.578	0.553	0.483	0.478
20	FAR	A	T	1.000	0.975	0.905	0.900
21	FAR	A	TR	0.916	0.891	0.821	0.816
22	FAR	R	A	0.888	0.863	0.793	0.788
23	FAR	R	R	0.550	0.525	0.455	0.450
24	FAR	R	AT	0.960	0.935	0.865	0.860
25	FAR	R	RAT	0.888	0.863	0.793	0.788
26	FAR	R	RT	0.747	0.722	0.652	0.647
27	FAR	R	T	1.000	0.975	0.905	0.900
28	FAR	R	TR	0.972	0.947	0.877	0.872

Figure 6. Example of utilities for reed canary grass management in floodplain forests. The first column is the distance class, the second and third columns show the state prior to and after treatment actions. The following columns are the transition probabilities for glyphosate (G), no action (NA), seeding (S), and glyphosate+seeding (GS).

4. Algorithm for computation of optimal state-specific decision policy for any arbitrary weighting of uncertain models

For a description of the algorithm, see final report "5. Identify decision structure and Dynamic Optimization" page 12.

5. Algorithm for model weight updating

For the forest models, each action has associated uncertainty. For rest, the two models are 1) distance does not have an effect ("no distance effect") on RCG competitive ability and species composition with no action (resting) and 2) distance does have an effect on RCG competitive ability and species composition ("distance effect") on resting. The same competing models are used for glyphosate. The prior distributions are defined as

– for the forest rest model weights and

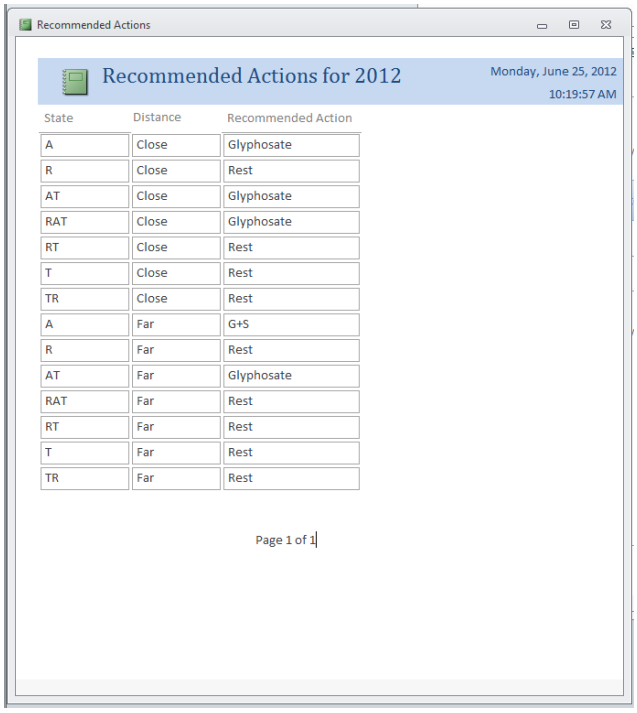
– for the forest glyphosate model weights. For both glyphosate plus seeding and seeding only, there are four models: distance does not have an effect and seeding does not have an effect ("no distance or seeding effect"); distance does not have an effect and seeding *does* have an effect ("no distance effect & seeding effect"); distance *does* have an effect and seeding *does not* have an effect ("distance effect & no seeding effect"); and distance and seeding both have an effect ("distance and seeding effect"). The

prior distributions are $\bar{\quad}$ for the forest glyphosate plus seeding model weights; and $\bar{\quad}$ for the forest seeding model weights.

The next component of Bayes' law is the likelihood function. In our case, the likelihood of each observation is defined as the transition probability for the competing model. For example, consider the forest rest model. Suppose we observe a plot in state 7 (a little or a lot of RCG and trees resistant to glyphosate), a rest is performed, and the plot remains in state 7. Under the "no distance effect" model, the likelihood of this transition is 0.718, while the likelihood under the "distance effect" model is 0.638. The denominator of Bayes' law is simply the sum of each models transition probability multiplied by its corresponding prior distribution. Since fewer models exist for each action in the forest system, we consider each plot as a new observation and do not average across all plots within a unit.

6. **Lookup of optimal action given the observation of each plot and the updated model weights**

   Below is the optimal policy for the forest states (see Final Report page 12 for a description of the policy generation process). We also generated the optimal policy using equal weights across all models to investigate what impact improve understanding of the uncertainties will have on the prescribed action. The assignment of equal weight reflects an initial admission of uncertainty about the system and initial presumption that any competing model is equally credible.



State	Distance	Recommended Action
A	Close	Glyphosate
R	Close	Rest
AT	Close	Glyphosate
RAT	Close	Glyphosate
RT	Close	Rest
T	Close	Rest
TR	Close	Rest
A	Far	G+S
R	Far	Rest
AT	Far	Glyphosate
RAT	Far	Rest
RT	Far	Rest
T	Far	Rest
TR	Far	Rest

Figure 7. Optimal forest policy using updated model weights

State	Distance	Recommended Action
A	Close	Glyphosate
R	Close	Rest
AT	Close	Glyphosate
RAT	Close	Glyphosate
RT	Close	Rest
T	Close	Rest
TR	Close	Rest
A	Far	Glyphosate
R	Far	Rest
AT	Far	Glyphosate
RAT	Far	Rest
RT	Far	Rest
T	Far	Rest
TR	Far	Rest

Figure 8. Optimal forest policy using equal model weights

The improved understanding of the competing models has caused a change in the optimal policy. Under equal model weights, the recommended action for state A (No RCG and no trees) in distance class "Far" is Glyphosate. However, when we generate the optimal policy using the updated model weights, we see that the optimal action for state A in distance class "Far" is Glyphosate plus Seeding. As we continue to learn more about the system, we can expect the optimal policy to change to reflect this improved understanding.

7. **Database to record and summarize actions and vegetation**

   An Access database was created and a description and user guide is provided in *C User Guide to the Decision Tool* on page 107.

   Pertinent Digital Supplement: Microsoft Access Database

C. User Guide to the Decision Tool

DECISION TOOL DESCRIPTION AND INSTRUCTIONS:

The RCGAM Decision Tool facilitates management of land to optimize the project's core objectives by supporting the following processes:

1. Standardized collection of monitoring data
2. Generation of recommendations for land managers based on obtained data
3. Dispersal of recommendations to land managers
4. Model updating which informs future policy for recommendations
5. Dispersal of model results and other desired summaries

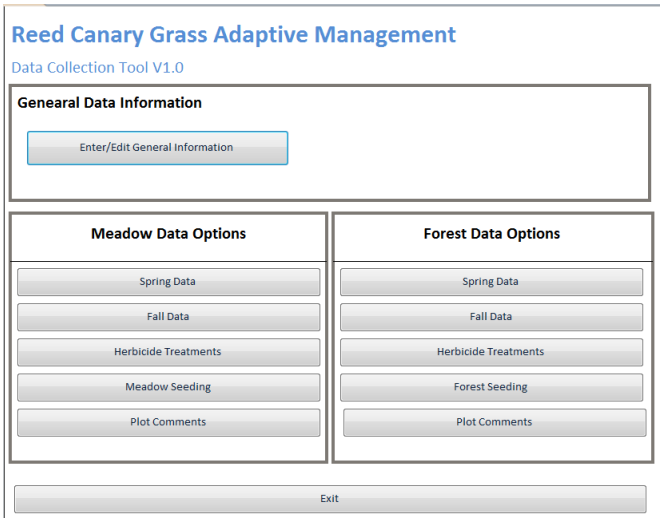
Benefits of using this tool:

1. The data is all in one format
2. The tool is user friendly
3. The coordinator can easily perform complicated model updating with the click of a button

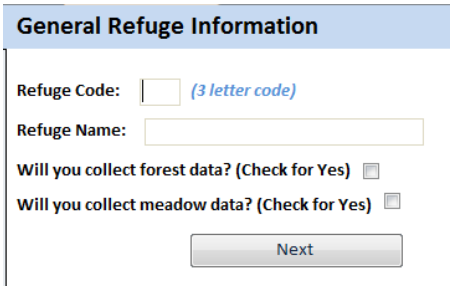
Brief Overview:
The tool has two components: an Access Database for land managers and a master access database for the project coordinator. Land managers will interact only with a local copy of the Access Database and will upload the populated database to the Basecamp site. The project coordinator will collate the data contained in each land manager's Access Database and import it to the master Access Database. Once all of the relevant data for a given season has been collected, the project coordinator uses the master database to generate recommendations for the land managers and uploads the recommendations to Basecamp to disperse the information. The master database is also used to perform model weight updating and to compute optimal decision policies based on the updated weights. As management history and vegetation response are collected in this database, the evolution of the model weights will influence future policy for recommendations.

INSTRUCTIONS FOR LAND MANAGERS

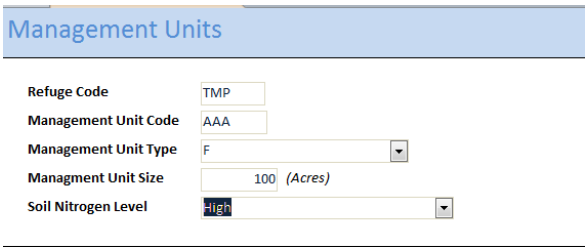
Land managers will be entering the field collection data into a Microsoft Access Database collection application each year they participate in RCGAM. A new copy of the application should be obtained each year and is available for download from the project's basecamp website. Once the application is opened, a main form is presented which has three sections for the information needed: a General Data Information section, a Meadow Data Options section, and a Forest Data Options section. Each button on the form will bring up other forms that correspond to the desired option where data can be entered.



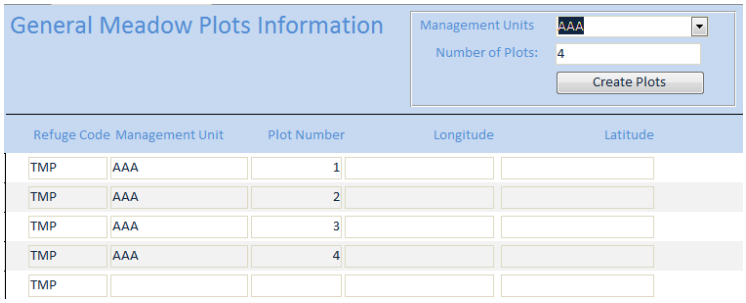
The first data that should be entered into the application is the "General Data Information" section. If a user clicks on the "Enter/Edit General Information" button, a series of forms will be presented to enter information about the refuge being sampled, the management units that are being sampled in that refuge, and the plots within those management units. These options appear for both meadow and forest data sites. The flow of the forms is as follows.



Some basic information is entered about the refuge being sampled and what is going to be sampled at the refuge. The user then should click "Next" to proceed to the next form.

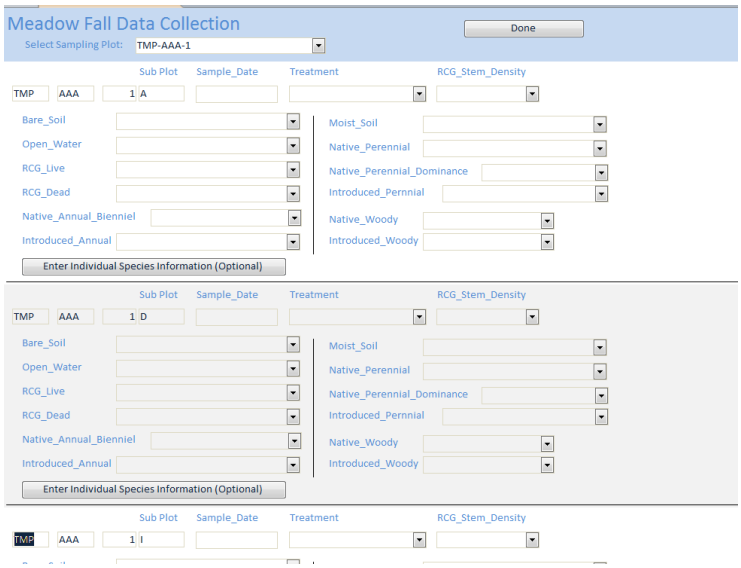


This form has information that needs to be filled out about each management unit within the refuge. A record should be entered for each unit, along with the size of the unit, nitrogen level of the soil in the unit, and the type of the management unit (forest or meadow). Once done filling out management unit information, the user should proceed by clicking "Next". The next three forms assist the user in setting up the plots within the management units for meadow and forest sites. The first form is provided to setup the plots within the meadow management units. To add plots, select the management unit from the drop down list in upper right hand corner, enter how many plots are within that management unit, and click the "Create Plots" button. Do this for each management unit that is designated as a meadow management unit. If geographical coordinates of the plots are known, they can be entered in identified fields once the plots are created.



Once all the plots have been entered for the meadow management units, the user can proceed by clicking "Next". The next two forms, which serve to setup the forest management units, are very similar to and function the same way as the General Meadow Plots Information form. The first form helps set up the transect information within forest management units, and the second form sets up the plots within those transects in the management unit. After all the information needed has been entered into the forest management unit forms, the user is presented with one last form for entering the names of any people that will be collecting sampling information. Entering the observers' information concludes the initial setup of the data collection application. The application is now ready to have data entered into it throughout the year, based on different events that occur during the collection year. From the main form there are two sections of options, one for meadow data entry and the other for forest data entry. The information that can be captured with the application (and that should be filled out throughout the year) includes Spring Data, Fall Data, Herbicide Treatments, Seeding Treatments and Plot Comments. The spring and fall forms are slightly different depending on the sampling protocols for the

different seasons and the different protocols used for meadow sampling or forest sampling. Dropdown lists are used wherever possible to help reduce data entry error. For the data collection portion, a user selects a sampling plot and then is presented with a form to fill out regarding the sampling of that plot. The image below shows an example Meadow Fall Data Collection form.

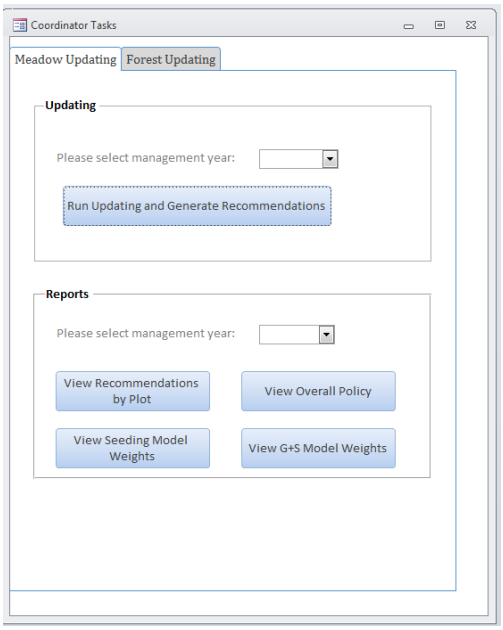


If for any reason special circumstances come up throughout the year, i.e. flooding or missed plot sampling, users make note of these exceptions in the plot comments form. This basic form that allows you to select a plot and then enter in a small text note about that plot. After all the data have been entered into the application for the year, the data collection application should then be uploaded back to Basecamp where the program manager will then import the data into the master database for analysis.

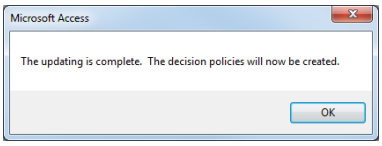
INSTRUCTIONS FOR THE WEBSITE OR PROJECT COORDINATOR

In addition to the Access Database for data entry, the project coordinator will interact with the Access Database that aggregates the data and uses that data to run and update relevant models. The project coordinator should decide beforehand where the database will be stored.

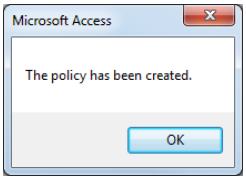
The Coordinator Tasks screen is displayed below. The Screen contains two tabs: one for Meadow Updating and one for Forest Updating. In the top section of each tab, an "Updating" subsection contains a drop down box to select the management year and a button to run the updating and generate recommendations. The drop down list only contains years for which actions have been recorded.



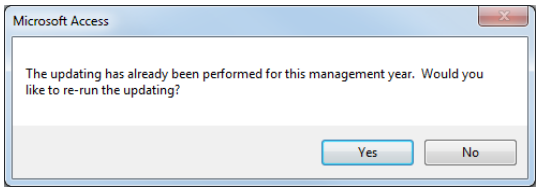
The coordinator proceeds by selecting a management year and clicking the button. Behind the scenes, the model updating and policy generation is performed. The coordinator will receive an alert when the updating is complete:



Another alert will appear indicating that the policy has been created:

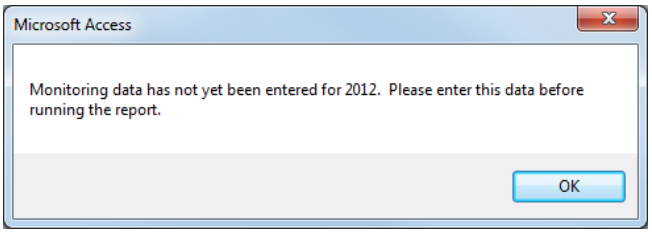


If the coordinator selects a year for which the updating has already been completed, an alert will appear:

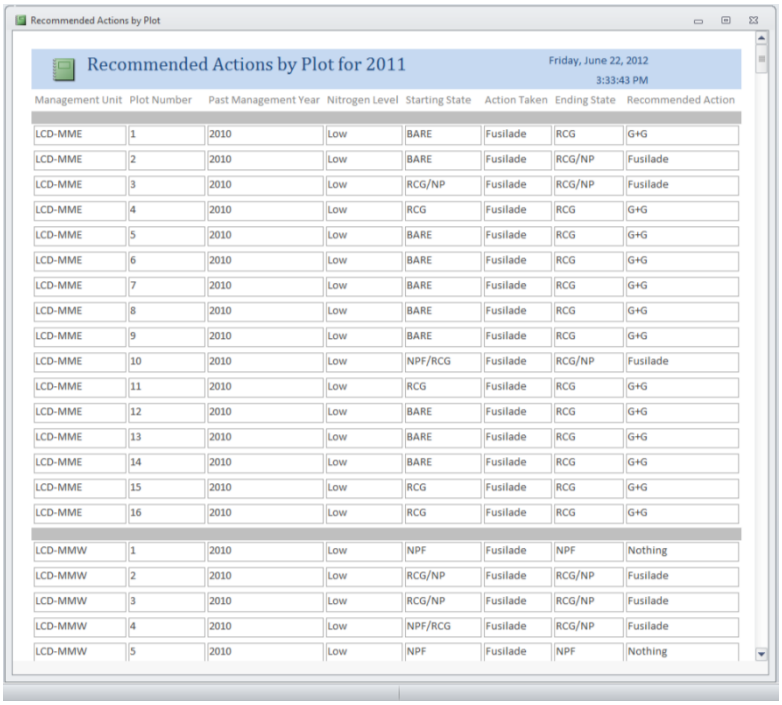


Once the updating has been completed, the Coordinator can then generate four reports: policy recommendations by plot, overall policy recommendations, seeding model weights and glyphosate plus seeding model weights.

First, the coordinator selects a year for which he/she would like to view the reports. Only years for which the policy has been created will be available in the dropdown. The policy recommendations by plot report requires that monitoring data for the recommendation year be entered. If the monitoring data has not yet been entered, an alert appears:

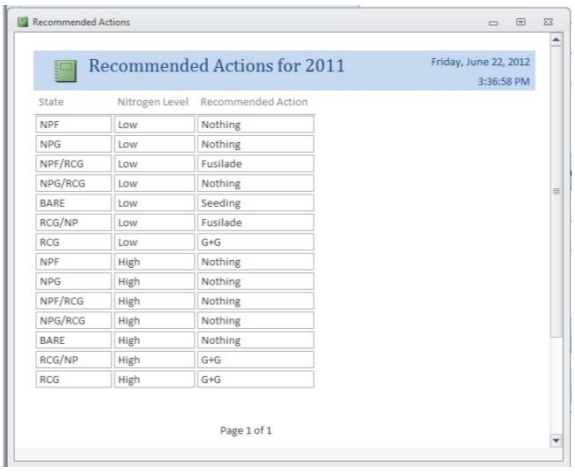


If monitoring data has been entered, the report appears. It contains the management unit name, plot number, previous management year, nitrogen level, previous state, previous action taken, current state and recommendation.



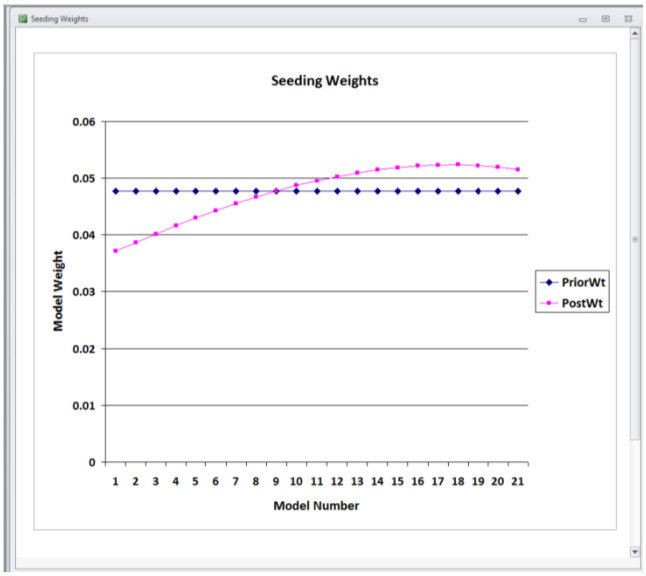
Management Unit	Plot Number	Past Management Year	Nitrogen Level	Starting State	Action Taken	Ending State	Recommended Action
LCD-MME	1	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	2	2010	Low	BARE	Fusilade	RCG/NP	Fusilade
LCD-MME	3	2010	Low	RCG/NP	Fusilade	RCG/NP	Fusilade
LCD-MME	4	2010	Low	RCG	Fusilade	RCG	G+G
LCD-MME	5	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	6	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	7	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	8	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	9	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	10	2010	Low	NPF/RCG	Fusilade	RCG/NP	Fusilade
LCD-MME	11	2010	Low	RCG	Fusilade	RCG	G+G
LCD-MME	12	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	13	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	14	2010	Low	BARE	Fusilade	RCG	G+G
LCD-MME	15	2010	Low	RCG	Fusilade	RCG	G+G
LCD-MME	16	2010	Low	RCG	Fusilade	RCG	G+G
LCD-MMW	1	2010	Low	NPF	Fusilade	NPF	Nothing
LCD-MMW	2	2010	Low	RCG/NP	Fusilade	RCG/NP	Fusilade
LCD-MMW	3	2010	Low	RCG/NP	Fusilade	RCG/NP	Fusilade
LCD-MMW	4	2010	Low	NPF/RCG	Fusilade	RCG/NP	Fusilade
LCD-MMW	5	2010	Low	NPF	Fusilade	NPF	Nothing

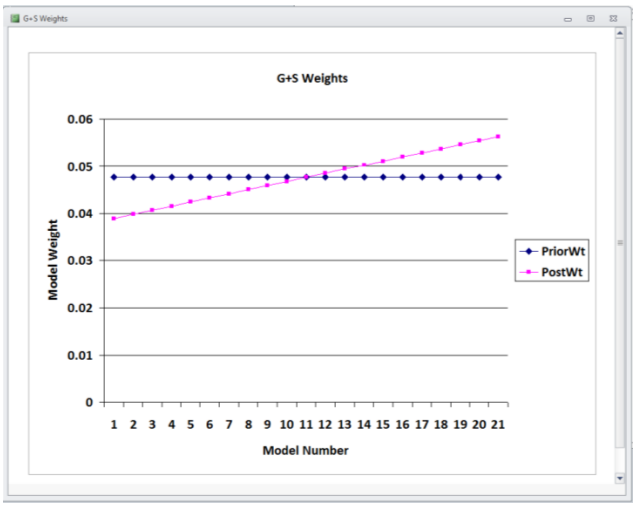
The coordinator can also choose to view the overall policy recommendations:



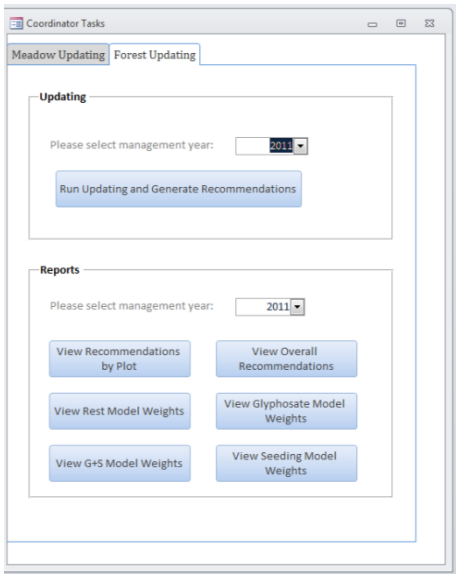
State	Nitrogen Level	Recommended Action
NPF	Low	Nothing
NPG	Low	Nothing
NPF/RCG	Low	Fusilade
NPG/RCG	Low	Nothing
BARE	Low	Seeding
RCG/NP	Low	Fusilade
RCG	Low	G+G
NPF	High	Nothing
NPG	High	Nothing
NPF/RCG	High	Nothing
NPG/RCG	High	Nothing
BARE	High	Nothing
RCG/NP	High	G+G
RCG	High	G+G

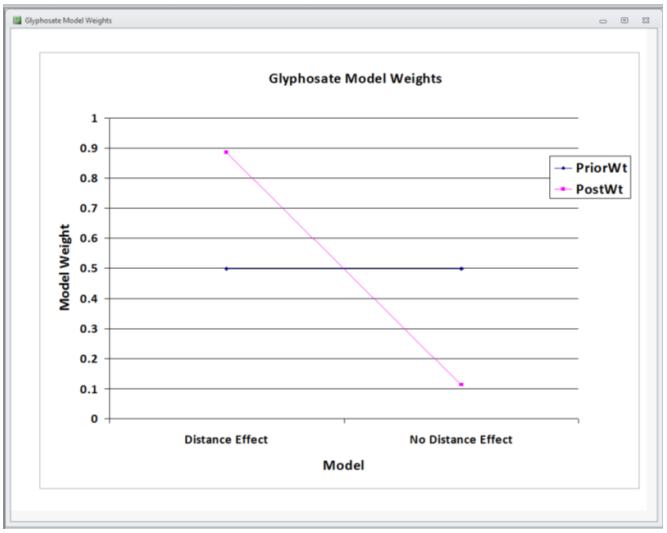
For each action with competing models, the prior and posterior weights are displayed in a report:

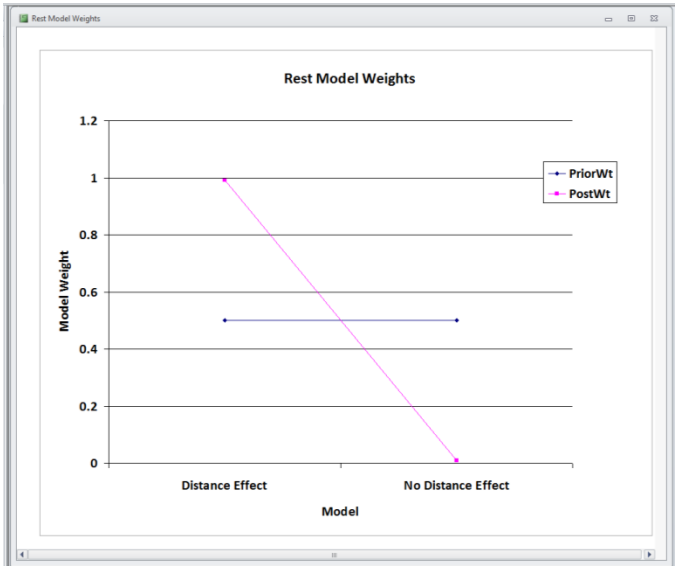


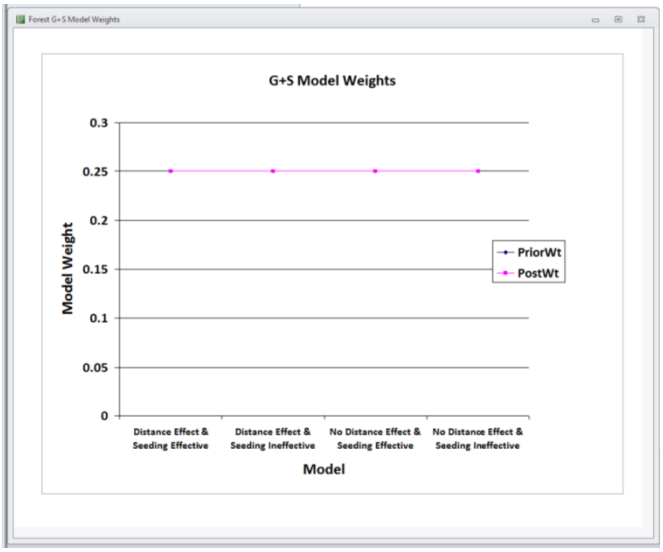


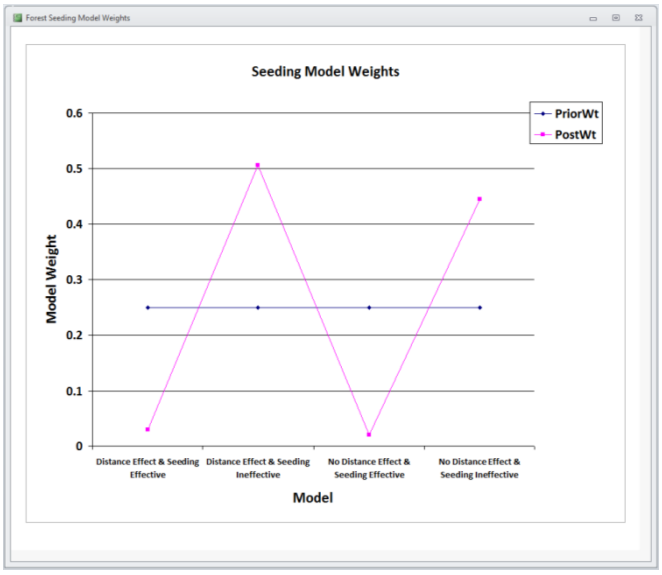
The process is identical for the Forest weight updating. The coordinator first clicks the button to run the updating and recommendation generation. Once the updating and policy generation is complete, the coordinator can view the recommendations by plot or the overall policy. In the case of the forest model, all four actions have competing models, so four model weight reports can be generated.


Coordinator Tasks
Meadow Updating
Forest Updating
Updating
Please select management year:
2011
Run Updating and Generate Recommendations
Reports
Please select management year:
2011
View Recommendations by Plot
View Overall Recommendations
View Rest Model Weights
View Glyphosate Model Weights
View G+S Model Weights
View Seeding Model Weights


Glyphosate Model Weights
Glyphosate Model Weights
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Model Weight
PriorWt
PostWt
Distance Effect
No Distance Effect
Model


Rest Model Weights
Rest Model Weights
1.2
1
0.8
0.6
0.4
0.2
0
Model Weight
PriorWt
PostWt
Distance Effect
No Distance Effect
Model





EXAMPLE PROCESS

The sequence of events below integrates both Land Manager and Project Coordinator actions to support the annual cycle of the Decision Tool.

1. Land managers before the sampling season begins should navigate to the Basecamp website (https://rcgam.basecamphq.com) and download a blank RCGAM data collection application.
2. Land managers then rename the collection application so that the filename references their refuge in some way so that it can be distinguished from other land managers' collection applications
3. Land managers should first enter all the information they can into the "General Information Section" of the collection application about their sampling sites

4. During various events throughout the year (spring sampling, fall sampling, management unit treatment, management unit seeding) the data should be populated in the collection application
5. Once all the data have been entered at the end of the collection year the collection application should be posted back to the Basecamp site
6. Once the data collection applications have been posted back to Basecamp the project coordinator should then import the data from the data collection application into the master sampling data database using the import tools provided in the master sampling data database
7. Once all the data is in the master sampling data database, Project coordinator should then open up the modeling tools database and click on coordinator tasks button
8. Project coordinator uses the modeling tools Access database to run the Bayesian model updating procedure incorporating the new monitoring data, generate reports of model weight results, compute the new optimal policies under the updated model weights, and generate recommendations.
9. Project coordinator uploads to reports to Basecamp
10. Land manager goes to Basecamp to view recommendations and results. Land managers give feedback to the project coordinator and technical issues are resolved. The cycle repeats in the next season.

II. Long term RCG management recommendations for each refuge:

Consistent with the DOI's policy on adaptive management, we recommend refuges follow the updated policies generated by the decision tool. These recommendations will be further refined through the use of the Decision Tool and by interactions with participants.

III. Recommendations for future AM projects

A. Recommendations for long term implementation of RCGAM

1. General recommendations:

- We plan for participation in the RCGAM Decision Tool to be facilitated by Basecamp https://rcgam.basecamphq.com for the 2012 field season. We will use Basecamp for to-do lists for participants and for the housing of all protocols. Also, Basecamp will be used to access the data entry; participants will download an Access database, enter data, and upload the revised Access database to Basecamp. We recommend further development of a Sharepoint interface for use after September 30, 2012.
- The responsibility for coordinating the RCGAM Decision Tool needs to be explicitly addressed by FWS. We recommend that the job description for the responsible parties make specific reference to RCGAM and duties associated with coordinating field actions, data retrieval, and model updating.
- Given that the Decision Tool has not yet been used in the implementation phase, we suggest limiting participation for the first two field seasons to already participating refuges. In addition to troubleshooting any facilitation issues, this would simplify the first round of using the tool, and handle the additional enrollment of units separately, after the first two growing seasons.
- We recommend that support at the level of the Refuge Managers be generated by upper level FWS where needed. The responsibility to generate participation and interest in RCGAM should not rest with FWS participants who have been dedicated to the initiation and building of the tool. Rather, clear direction from supervisors that Refuge Managers support AM activities is needed.

2. Coordination structure for long term RCGAM implementation

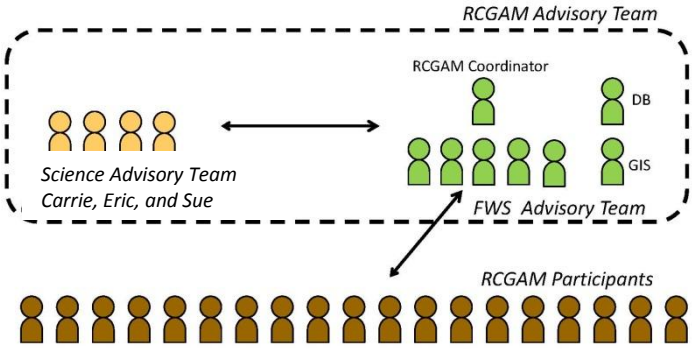


Figure 9. Recommended coordination and implementation structure for RCGAM

We recommend that long term implementation of the RCGAM Decision Tool be coordinated in the following way (Figure 9). Recommended implementation structure largely follow those designed to facilitate the Native Prairie Adaptive Management (NPAM) program (Ganon et al. 2012). Coordination roles should be as follows:

A. RCGAM coordinator
    1. Initial verification of data
    2. Facilitating Decision Tool function
        a. Entering data from submitted Access databases into master Access Database
        b. Pushing buttons to process data and generate recommendations
            1) Pull out model predictions and compare to data
            2) Model weight updating
            3) Selection of new decision actions for each participating unit based on updated model
    3. Facilitating field effort
        a. Entering new units
        b. Fielding questions about protocol
        c. Facilitating field participation via reminders and assistance with data
B. Participants: report vegetation data and implement actions
C. RCGAM Advisory Team:
    a) Troubleshoot issues with implementing recommendations, updating the Decision Tool, and adding new units
    b) Review request to use data outside of the decision-making process
    c) Conduct ancillary analysis of data for publication
    d) Ensure integrity of project in the long term
    e) Consists of
        a. RCGAM Coordinator

b. FWS Advisory Team (current regional coordinators and overall coordinator)
    1. Including a few station leaders in the FWS Advisory Team would be helpful to give the field perspective
c. Science Advisory Team (current Science Team)

3. **Special topics:**

- Access to the partially developed ArcGIS interface Decision Tool will be provided. We could not further develop this tool within the project timeframe, and recommend further development of this tool via a separate contract. Further refining the GIS interface to link directly to the Decision Tool is critical for stations that are engaged with RLGIS.
- The current Science Team will serve in an advisory role. Regarding academic personnel, the feasible level of commitment may be different than that for agency personnel. Universities mandate that academic personnel effort match grant dollars that support their programs. Limited contact (occasional phone call) would be appropriate without additional funding, but regular contact would require an additional contract.
- We selected a limited number of treatments to include in the Decision Tool in order to focus learning on these treatments. Treatments were chosen for the promise they indicate in experiments reported in the literature and their feasibility of implementation in a real-world refuge context. New treatments may be attempted by RCGAM participants, however, for treatments not attempted by a large number of refuges for many years, the rate of learning will be slow. We recommend that any new treatments be carefully considered for their efficacy and feasibility. Recording details of implementing the new treatment, and following the standard monitoring protocol to collect response data, will both be critical to learn from these efforts.

B. Recommendations for other future AM projects

For recommendations for the early stages of AM, see final report, *Recommendations for future AM projects from RCGAM research/setup phase*, page 29. Below we list recommendations for transitioning to the implementation stage.

- Pulling together many years of previous work on the Decision Tool can exceed the time required for collaboration of the Science Team in earlier phases of the project. We held twice weekly 2 hour conference calls for the last 2 months of the project granting period to incorporate monitoring data, the Decision Tool, and the user experience.
- Frequent communication towards the end of the research phase with USFWS biologists and USGS project administrators facilitates a collaborative approach to ensuring that the end product of the work is most likely to be useful to biologists. Because the end products from AM efforts can range considerably, this frequent communication ensures that grant deliverables are met, and reasonable expectations for deliverables are fulfilled.

IV. Protocols for data collection suitable for long term monitoring

A. Changes in Monitoring Protocol from the Research phase (2008-2011) and Justification

Compared to the monitoring protocol during research phase, the long term protocol is considerably reduced. We revisited our monitoring approach with an extensive literature review, and determined that the basic structure of both the meadow and forest monitoring is optimal for our purpose of long term monitoring. Plot based monitoring, as the system used here, is best for repeat, long-term sampling (Sutherland 1996).

Sutherland WJ. 1996. Ecological census techniques: a handbook. Cambridge University Press, Cambridge, UK.

Modifications to the protocol were made in an attempt to decrease monitoring effort without compromising the quality of the decision tool. The data collected during 2008-2011 allowed us to perform a sensitivity analysis. We performed quantitative sensitivity analyses to ensure that only the necessary monitoring effort is required to participate in the study. We eliminated monitoring that does not relate directly to the data needed for the model. We retained several monitoring parameters that show promise in improving predicted management outcomes.

Optional Protocol for Meadows: If time allows, and only after full monitoring is complete as described in the Long term monitoring protocol, collection of single species data will be useful for further analysis and Decision Tool development. See OPTIONAL protocol see Basecamp for protocols and data sheets.

1. Reductions in Wet Meadow Monitoring

The major change in Meadow monitoring is that data will only be taken on the 4 corner subplots per plot (instead of 12 subplots per plot, Figure 9). Also, previous protocol called for collecting individual species cover, but the long term protocol calls for collecting guild cover only. In addition, the only data collected in spring will be RCG stem density (the decision tool uses the fall data to monitor response from other vegetation). Guild cover classes will be collected for fall data (no single species data needed). Also, native perennial guild will be divided by graminoid (true grasses) and non-graminoids (including rushes, sedges, and forbs). See appendix 4 page **Error! Bookmark not defined.** for assistance on distinguishing graminoids and non-graminoids.

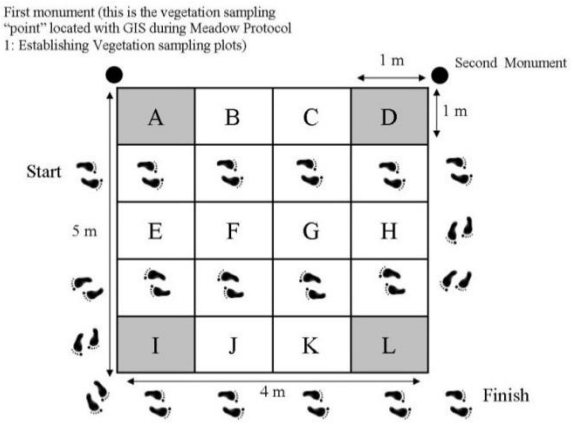


Figure 10. Meadow experiment vegetation sampling plots. Plots are divided into subplots, 4 of which are sampled for vegetation data (shaded gray). Footprints indicate the path in which to walk to avoid trampling of plots to be sampled.

Concerns were raised that the current monitoring protocol was labor intensive and time consuming. A sensitivity analysis was conducted to determine the number of subplots to monitor while maintaining a high level of accuracy. For each subplot layout combination (Table 1), 100 iterations were performed to determine the dominant guild.

Table 1. Sensitivity analysis to determine the number of subplots to monitor while maintaining a high level of accuracy. Subplot layouts refer to the number of subplots or columns used in the analysis. A column for example is the vertical alignment such as subplots A, E, I.

Subplot Layout	Accuracy compared to full monitoring (%)	Effort compared to full monitoring (%)
Corner (4 subplots)	83.3	33.3
Edge (6 subplots)	88.6	50.0
1 Random Column (3 subplots)	82.2	25.0
2 Random Columns (6 subplots)	89.4	50.0
3 Random Columns (9 subplots)	93.8	75.0
1 Random Subplot	65.3	8.33
2 Random Subplots	75.4	16.7
3 Random Subplots	79.7	25.0
4 Random Subplots	81.9	33.3
5 Random Subplots	85.4	41.7
6 Random Subplots	87.6	50.0
7 Random Subplots	88.8	58.3
8 Random Subplots	91.2	66.7
9 Random Subplots	92.9	75.0
10 Random Subplots	93.8	83.3
11 Random Subplots	96.5	91.7
Full monitoring (12 subplots)	100	100

The long term protocol has been modified to only collect data from the four corner subplots A, D, I, and L (Figure 9). This reduces the effort by 33% while maintaining 83% of

the accuracy of the full 12 subplot protocol with an acceptable standard deviation (Table 1; Figures 10, 11).

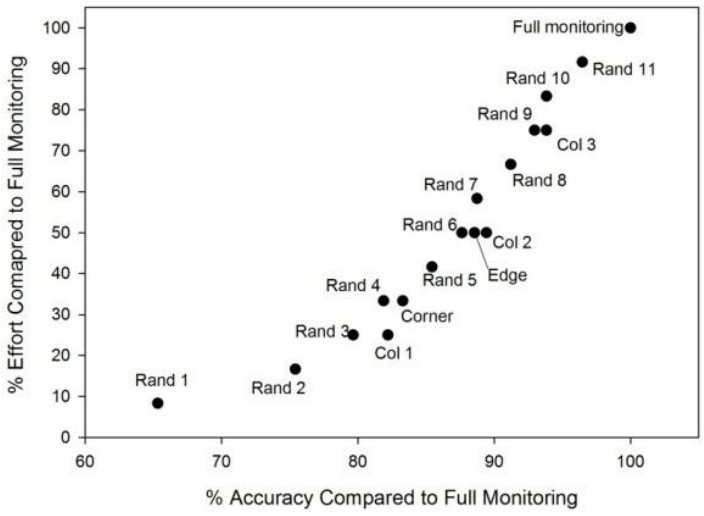


Figure 11. Scatter plot of subplot monitoring method. The y-axis represents percent effort compared to the full monitoring protocol, and the x-axis represents percent accuracy compared to the full monitoring protocol. Full monitoring represents 100% accuracy and 100% effort.

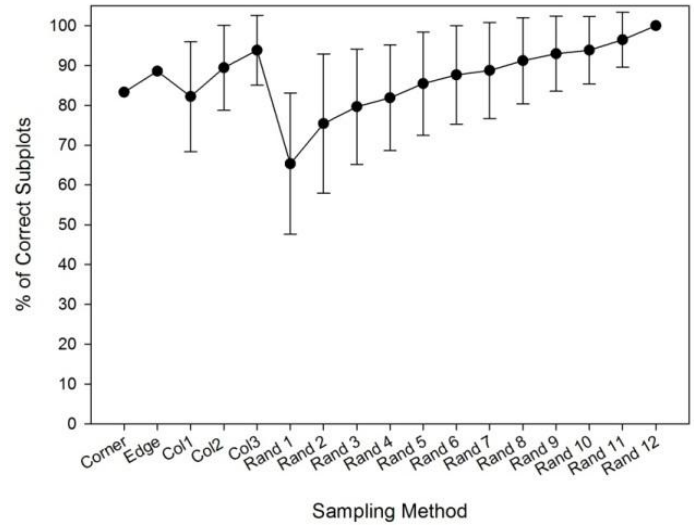


Figure 12. Line graph of subplot monitoring method. Each point represents the average of 100 iterations in determining the dominant guild compared to the full 12 subplot monitoring protocol. Bars represent standard deviation.

Dividing the native perennial guild is necessary because graminoids are more susceptible to fusilade than non-graminoids, and this impacts the decision tool and recommended actions. It is necessary to distinguish between sedges, rushes, and true grasses

(graminoids) because sedges and rushes are not true grasses and will be included in non-graminoids along with forbs. See the meadow monitoring protocol appendix 4 page 26 for assistance on distinguishing grasses from rushes and sedges.

2. Reductions in Floodplain Forest Tool Monitoring

Herbaceous vegetation data will no longer be taken (no guild data, no single species data).An unexpected outcome of glyphosate treatments to forest management units was the establishment of high quality meadow vegetation. To facilitate recognition of this kind of outcome by the decision tool, we must keep track of native wet meadow herbaceous cover to give users the option of changing their objective (managing for wet meadow instead of managing for forest). Monitoring for this trigger will be as follows: if the plot has greater than 50% native herbaceous cover observers will mark yes; if native herbaceous cover is less than 50% observers will mark no. This is recorded on every plot. If the plot is >50% native herbaceous another tool may be considered, such as the wet meadow tool.

Note: If there are no trees and no RCG but other vegetation, this Decision Tool to support management on RCG invaded lands may not be needed. Or, if there is native vegetation, such as a wet meadow, a forest tool may not be needed.

B. Long term monitoring protocols

See Appendix 4 for long term monitoring protocols.

V. Publications resulting from this work

Reinhardt Adams, C. and P.J. Kauth. 2012. Novel ecosystems persist following *Phalaris arundinacea* control. 9th INTECOL International Wetlands Conference (invited symposium). June 4, 2012. Orlando, FL.

Larson, J. and C. Reinhardt Adams. 2011. How can natural seed rain from adjacent floodplain forests assist revegetation following Reed canarygrass invasion? Bottomlands Restoration Ecosystem Conference. Collinsville, IL.

Reinhardt Adams, C., P. J. Kauth, and J. W. Sorenson. 2011. Assessing competition between reed canary grass (*Phalaris arundinacea* L.) and swamp white oak (*Quercus bicolor* Willd.). *Ecological Restoration* 29: 332-338.

Reinhardt Adams, C. 2009. Adaptive Management for invasive species dominated landscapes. University of Florida Wildlife Ecology and Conservation Fall 2009 Seminar series. September 21, 2009. Gainesville, FL.

Reinhardt Adams, C. and J.W. Sorenson. 2009. Floodplain forest seed rain shows variable potential for forest regeneration. Ecological Society of America. Albuquerque, NM.

Reinhardt Adams, C. and C. Moore. 2009. Directing succession through adaptive management: Reed canary grass control and transition to wetland forests and meadows. Southeastern Adaptive Management Group (SEAMG) Steering Committee Meeting. May 7, 2009. Gainesville, FL.

Sorenson, J. 2009. Assessing competition between Reed canary grass (*Phalaris arundinacea* L.) and Swamp white oak (*Quercus bicolor* Willd.): a greenhouse experiment. Masters Non-thesis paper, presented April 14, 2009.

Reinhardt Adams, C. 2009. Evaluating management options for invasive species dominated landscapes. Archbold Biological Station Seminar Series (invited presentation). April 2, 2009. Lake Placid, FL.

Reinhardt Adams, C. and N.M. Steigerwalt. 2008. Poster: Direction Succession Through Adaptive Management: RCG in wet meadows and forest floodplains. FL Fish and Wildlife Coop Unit Coordination Meeting, Gainesville, FL.

Sorenson, J.W. and Reinhardt Adams, C. 2008. Poster: Evaluating restoration potential of floodplain forest ecosystems along the upper Mississippi River following eradication of reed canary grass (*Phalaris arundinacea* L.). FL Fish and Wildlife Coop Unit Coordination Meeting, Gainesville, FL.

Appendix 4 RCGAM Protocol Guidebook. Contains protocols for participation in RCGAM, including establishing new management units, data collection protocols and treatment implementation protocols.

RCGAM Protocol Guidebook:
Establishing new management units, data collection for long term monitoring, and implementing treatments.

Reinhardt Adams, C., S. Galatowitsch, E. Lonsdorf, P. Kauth, and K. Carlyle. 2012.
USGS Biological Resources Division
USFWS Biological Monitoring Team

Management Unit Monumenting and Long Term MonitoringData Collection Protocols

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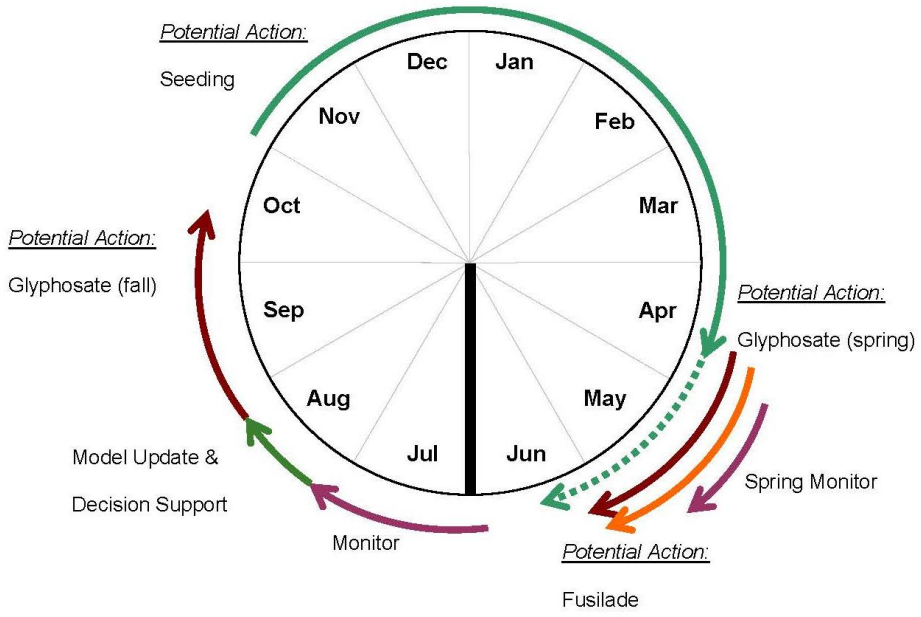
RCGAM Timeline



Fall Season

- Data collection
  - ✓ Collect by August 20
  - ✓ Enter into database by August 25
  - ✓ Recommendations by Sept 1
    - National Decision Analysis Day
- Actions
  - ✓ Glyphosate by September 1
  - ✓ Seeding in late fall or winter

Spring

- Data collection
  - ✓ Collect data by June 10
  - ✓ Enter into database by June 15
- Actions
  - ✓ Glyphosate by June 1
  - ✓ Fusilade by RCG anthesis (May/June)
  - ✓ Seeding in early spring or dormant seed over winter

Coordinator and Decision Tool Actions--Between Aug 25 and Sept 1

- Coordinator performs overview to evaluate flagged records – mainly actions
  - Use Year 1 to help develop flag rules
  - Makes changes/accepts/excludes
- Queries produce tables of input for decision tools
  - Model weights updated
  - SDP is run
  - Action recommendations made
- Reports generated
  - Actions
  - Vegetation summaries for cooperator

Definitions

These definitions will be used throughout this document.

Management unit: the area receiving the management treatment. The entire management unit will be treated similarly with respect to herbicide treatments, revegetation efforts, etc.

Plot: the area in which vegetation sampling occurs. A management unit has multiple plots.

Subplot: a smaller area within the plot in which vegetation sampling occurs. A plot has multiple subplots.

Points: the location of a corner of a plot or subplot.

Labeling Scheme

Consistent labeling across participating refuges and across sampling times will be critical. The labeling system will obey the following rules:

- Use an official 3 letter refuge code for the first part of the label, then a dash, then an official 3 letter management unit code, then a dash, then any plot number designations.
- Do not use numerics in refuge or management unit codes; numerics are reserved for plot numbers.
- Refuges with forest and meadow management units should have one letter in the management unit code indicating F or M.
- Example: A La Crosse district meadow unit: LCD-MME-10; and a forest unit: LCD-RSF-2A.

Monumenting Protocol for New Management Units

Ecological Objectives: By repeat sampling in the same location, we reduce variability in plant community data associated with spatial heterogeneity within the management unit. Marking plot location permanently will allow us to more accurately assess response, as we will have eliminated the possibility that differences in plant community data are simply due to sampling in a different location.

Goal: To monument points that designate corners for vegetation sampling plots in a manner that makes them easy to find, ensures repeated observations in the same location, and does not interfere with study treatments. This protocol is for use after point locations have been established.

Personnel: Points are most efficiently monumented with two people.

Timing: Once prior to pretreatment data collection.

Equipment: GPS unit (or compass), rebar, hammer, point identification tags, permanent marker, florescent marker spray paint and PVC

Note about flexibility: There is flexibility with monumenting protocol. The objective is for the monumenting to ensure that the vegetation sampling plot boundary can be easily identified upon repeat visits, and the subplot layout is properly aligned.

Note about interference with herbicide application: Monumenting cannot interfere with herbicide application, so be sure to have monuments that ensure uniform coverage across the management unit and do not interfere with herbicide application equipment. However, note that while low markers interfere less with herbicide applications, they will likely be very difficult to relocate. Relocating hidden monuments can add significant time to sample and increase the possibility that plots that will need to be sampled will be trampled, compromising data quality.

1. Determine the amount of monuments needed for required vegetation sampling points.
    a. For Forest Management Units, 9 points (and 9 markers) per transect are needed (minimum of 3 transects, or 27 points per management unit). Because the number of points will be dependent upon the shape (as well as the size) of the management unit, confirm the plot layout with your regional coordinator.
    b. For all Meadow Management Units, 8 sampling plots per acre are needed. We will use two monuments per sampling plot, so 8 plots/acre x 2 monuments/plot =16 monuments/acre are needed. Plot layout will be random across Meadow management units.

2. Gather supplies for monuments. The recommended monumenting scheme is shown in Figure 1 (other designs, if the monument does not interfere with herbicide applications and is easily relocateable, may be appropriate). Supplies for the recommended monumenting scheme include the following for each monumented point:
    a. One 5 ft section of rebar to serve as a permanent marker.
    b. One 5 ft section of PVC to serve as a locator marker.

3. Install rebar marker. Hammer into the ground deep enough to prevent removal with frost heave (4 ft into the ground), leaving 6-12 inches of rebar above ground. Take precautions to mark the rebar to make it easily relocateable. For instance, to increase visibility of this marker, spray paint the rebar with a bright

color, mark the point with tractor disks, or use "stake chasers" available from a variety of vendors, including http://www.smicarr.com/.

4. Attach point identification tag (anything permanent that will not fade over time) and record point name on tag. Each point should be permanently labeled with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number (see "Labeling Scheme, above"; using the protocol to accurately and uniformly label samples and sampling plots consistently is critical).

5. To make the monument more visible, add the removable 5 ft PVC locator marker on top of the rebar.

6. Record point name on PVC locator marker (anything permanent that will not fade over time—not most Sharpie markers) and place over the conduit permanent marker. This PVC tube will be removed during treatment applications, so it should not fit so snuggly that it will be difficult to remove.

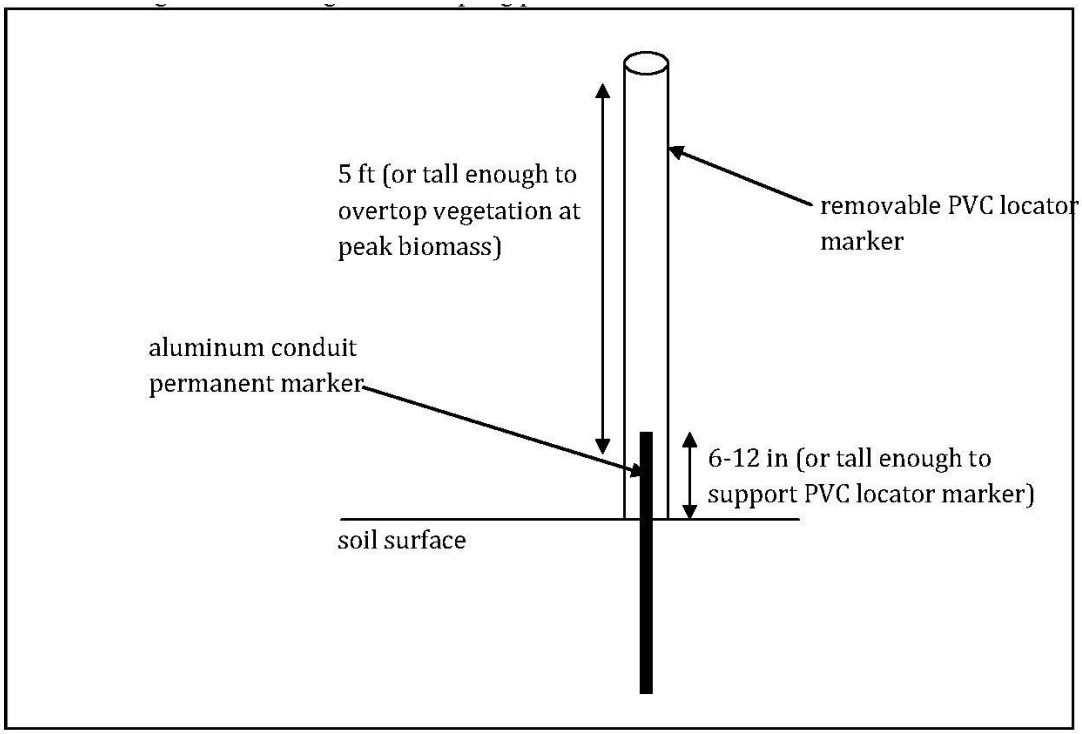


Figure 1. Monument for Vegetation Sampling Points.

New Meadow Vegetation Sampling Plots

Ecological Objectives: To establish repeated-measurement vegetation sampling plots randomly across a meadow management unit. The plots need to be randomly located to accurately characterize vegetation cover across the management unit, and the plots need to be permanently located to ensure repeated measurement in the same location.

Goal: To randomly locate 4m x 5m meadow vegetation sampling plots.

Personnel: Establishing vegetation sampling points is most efficiently performed with two people.

Timing: Once prior to pretreatment data.

Equipment: GPS unit, measuring tape, monumenting supplies (see Monumenting Protocol for New Management Units). GIS maps will be useful, but not absolutely necessary.

1) Use ArcGIS to generate random locations for each 4m x 5m vegetation sampling plot, with 8 plots per acre (and a minimum of 8 plots per management unit). Locate plots such that the entire polygon lies at least 10 m from the management unit boundaries, and such that no plots are overlapping. When topographic rise is discernible, locate the 4m stretch of the plot perpendicular to the rise in elevation (see Figure 2 for clarification).

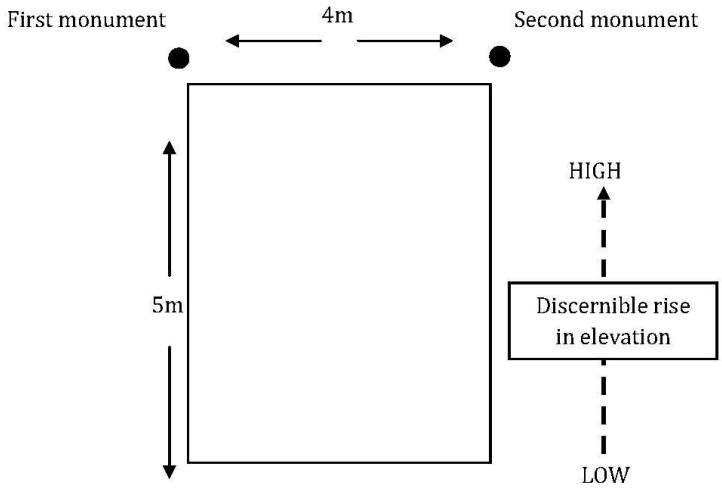


Figure 2. Meadow plot staking diagram. Plots are laid out, such that when topographic rise is discernible, the 4m stretch of the plot is perpendicular to the rise in elevation. Note the location of the first monument (upper left corner) and the second monument (lower right corner).

2) Permanently mark the plot (see Monumenting Protocol), by monumenting the corners of the plot. First, mark the LEFT corner that is highest in elevation. For the second monument, mark the RIGHT corner that is highest in elevation. Use GPS to record location of vegetation sampling points.

3) The LEFT corner monument should be permanently labeled with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number. For plot number, use a unique number for each plot (if there are 16 plots, number plots from 1 to 16). Plots must be consistently labeled with the same number from year to year and from data collection to data collection. For this reason, permanently number the plots on the GIS map of plot locations, and use this map as a guide in the field during every data collection period.

New Forest Vegetation Sampling Plots

Ecological Objectives: Recolonization of the native forest community following RCG control is likely to be dependent on the distance from the forest edge. To determine how native community and RCG response to control treatments differs with distance from the forest edge, vegetation sampling plots must be stratified across this pertinent distance. In addition, plots must be permanently located; by repeat sampling in the same location, we reduce variability in plant community data associated with spatial heterogeneity within the management unit.

Goal: To systematically locate 8m x 8m vegetation sampling plots for the Forest Experiment.

Personnel: Vegetation sampling plots will be most efficiently established with two people.

Timing: Prior to pretreatment data.

Equipment: GPS unit, measuring tape, monumenting supplies (see Monumenting Protocol), flagging.

1) Identify the sampling baseline which represents the transition from forest to RCG. This line will be approximately straight, following the "drip-line" of the canopy edge (Figure 3). For forest edges that are uneven, this line should connect the outermost trees.

2) Determine the length of the baseline in meters from the corner of the management unit. For baselines over 80 m long, locate the starting point of the first transect 20 m from the beginning of the baseline. With your back to the forest, the baseline begins at the furthest point to your right. Additional transects will be located at 20 m intervals. Thus, you will have three transects for an 80 m baseline, 4 for a 100 m baseline, 5 for a 120 m baseline. There should be no transects within 10 m of the end of the baseline.

3) For baselines less than 80 m long, locate the starting point of the first transect 10 m from the beginning of the baseline, so that you position 3 transects within the plot. For baselines less than 60 m, you will locate transects 10 m apart (not 20) so that you have 3 transects.

4) These starting points are the beginning of transects running perpendicular to the forest edge out into the RCG-dominated area. Permanently mark the points (see Monumenting Protocol).

5) Along the perpendicular transects, vegetation sampling points will be located at 5 distances from the baseline (0, 10, 25, 45, and 80 m (or maximum distance if less than 80 m)) from the baseline (true edge of the forest). See Figure 3 for example of a layout of sampling points and corresponding vegetation sampling plots.

6) Each vegetation sampling plot should be labeled with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number. Plot number is determined by transect and distance from forest edge. See **Error! Reference source not found.** for an explanation of plot numbers. This label should be placed on the monument indicating the original sampling point located along the transect.

7) An additional monument should be added to the diagonal corner of every vegetation sampling plot (see lower right corner of **Error! Reference source not found.** for elaboration of this monumenting scheme). This additional diagonal monument will ensure that plot placement is the same for every data collection.

8) For forest edges that are uneven, additional plots should be placed on the forest side of the baseline at 10 m distances if the entire 8 m x 8 m plot will be located so there is no tree canopy overhead (Figure 3).

9) For management units with uneven forest edges, confirm the plot layout with project coordinator before proceeding.
10) Use GPS to record location of the starting points and vegetation sampling plots.

Vegetation sampling points for the Forest Management Units:

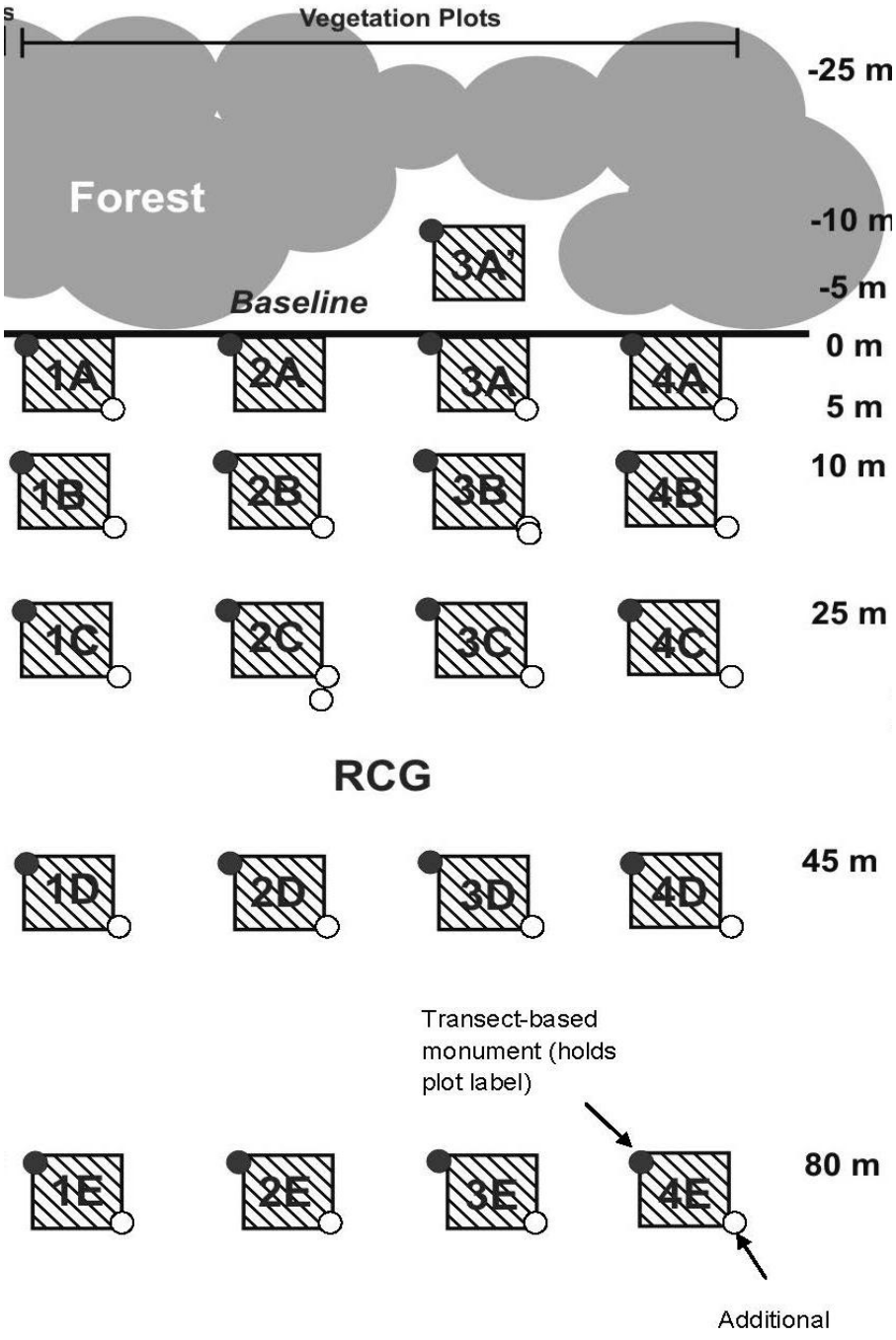


Figure 3. Vegetation plots (hatched squares) are located at 0, 10, 25, 45, and 80 m from the baseline into the RCG and (as needed) into gaps along the forest edge. Vegetation sampling points are labeled according to transect (number) and distance from edge (letter). See lower right corner of this figure for elaboration on the monumenting scheme for every plot. **Note:** each plot is positioned so it is to the right of the sampling point (see definitions above) when facing the forest.

Long Term Meadow Vegetation Sampling Protocol

Ecological Objectives: The experimental phase of the Reed Canary Grass Adaptive Management Project resulted in determination of key vegetation measurements needed to inform the RCGAM decision tool and to enable generation of management recommendations. Key measurements prior to and after treatment are RCG stem density and percent cover for vegetation and cover guilds. Data must be collected with the same methodology and lack of bias during each sampling event.

Goal: To obtain a measure of RCG stem density and the percents of vegetative cover and ground cover guilds from particular vegetation sampling plots within a meadow management unit.

Personnel: Vegetation sampling may be performed with one or two people.

Timing:
1. Spring (when RCG is greening up—likely April or May): RCG stem density counts
2. August (during peak biomass, likely mid-August): RCG stem density counts and guild vegetation data
Note: timing should be interpreted with respect to phenologic delay and local adjustments due to climate—more southerly locations may need to take vegetation sampling data earlier.

Equipment: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with subplot location (flags, string, etc.), GPS unit if needed and one data sheet for each sampling point (see Meadow vegetation sampling data sheet).

Stem density and cover guild sampling is to be conducted in each of the vegetation sampling plots identified during plot layout (refer to New Meadow Vegetation Sampling Plots protocol).

Each time you sample a plot please:

- **Record plot location on data sheet:**

    1) For each vegetation sampling plot, label Meadow vegetation sampling data sheet with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number (refer to New Meadow Vegetation Sampling Plots protocol for plot numbering scheme). Record this plot label on the Meadow vegetation sampling data sheet.

    2) Note herbicide treatment code for each plot (see data sheet for code explanation and Recording Plot Herbicide History guidance, page 28).

- **Locate subplots to be sampled:**

    1) Place the 1m x 1m frame in the "upper left" corner of the vegetation sampling plot marking the corner of the plot, and framing subplot A (see Figure 4 below). Avoid trampling the vegetation in the subplots to be sampled. If vegetation is very tall, it may be necessary to remove one side of the frame and reconnect the frame around the vegetation.

    2) The same subplots, A, D, I, and L, will be used for stem density and for fall cover guild sampling. Subplot labeling will remain consistent with the labeling used during the experimental phase when all lettered subplots were sampled (see Figure 4 below).

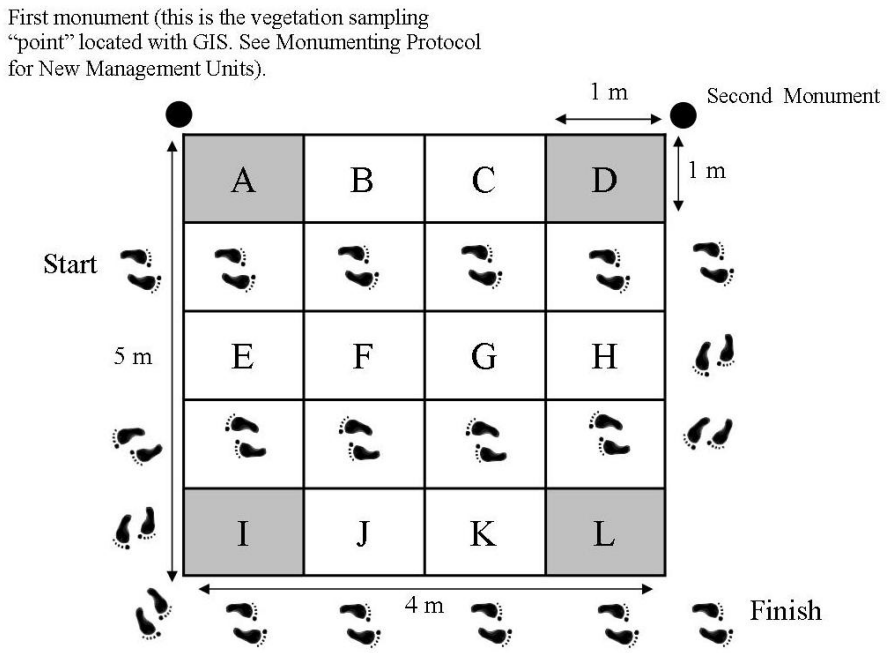


Figure 4. Subplot sampling diagram. Long-term monitoring data will be taken from the 4 corner plots A, D, I, E.

Spring and August ("Fall") RCG Stem Density Sampling:

This protocol is required during the spring vegetation sampling and the fall (maximum bio-mass) vegetation sampling. **RCG stem density is the only protocol required in the Spring**.

1) Estimate stem density of RCG (rhizome-based shoots AND seedlings) in 1m x 1m subplots A, D, I, and L (see Figure 4 above).
    - Stems are shoots that are green or shoots that have begun to senesce in late season. Both should be counted as stems. Observe RCG stem density in each shaded 1m x 1m subplot.

2) Record stem density codes (see Table 1 below) on plot data sheet for each of the four subplots.

Table 1. RCG Stem Density Category Codes:

Code	Stem density (stems/m^2)
1	0
2	1-10
3	11-50
4	51-100
5	101-200
6	201-500
7	501-1000
8	1001-2000
9	>2001

Late Season (Fall) Only Vegetation Cover Guild Sampling:

This protocol is to be used as well as the Stem Density protocol, above, during fall vegetation sampling.

The same subplots, A, D, I, and L (see Figure 4 above), used for stem density will be sampled to determine cover codes for vegetation guilds and ground cover type. (If optional species level data collection is desired please refer to OPTIONAL Species Level Sampling Protocols and data sheets on on pages 37-50.)

1) You may bring the "Master Plant List with Guilds" with you into the field for reference during fall data collection. During previous project years a comprehensive species list was created. Species life history and introduced vs native status ("**guild**") was determined. This information is used to estimate cover categories during fall sampling. The "Master Plant List with Guilds" is provided in a digital Excel file labeled: Master Plant List with Guild form. It contains all commonly encountered plants with current name spelling, form (**graminoid** vs **non-graminoid**), and **guild**. Unknown plants or plants encountered that do not appear on the Master Plant List can be checked on the USDA Plants Database, http://plants.usda.gov/.

2) Vegetation guilds and ground cover types to be determined
    a) Bare soil
    b) Open water
    c) RCG lv
    d) RCG dd
    e) RCG sn
    f) Native perennials (does *not* included RCG); You will indicate dominance in this guild:
        - "**G**" for graminoid (true native grass) dominance or
        - "**N**" for non-graminoid (sedge, rush, native forbs) dominance.
    g) Introduced perennials (*does* include RCG)
    h) Native annuals/biennials (herbaceous species)
    i) Introduced annuals/biennials (herbaceous species)
    j) Native woody species (shrubs and trees of any height)
    k) Introduced woody species (shrubs and trees of any height)
    l) Moist soil, not a true "guild", but a composite cover category including:
        - native annuals/biennials
        - introduced annuals/biennials
        - bare soil (see step 5a below)

3) For each cover type or plant guild over 1% aerial cover, estimate the fraction of the subplot occupied by the cover. Use table two below to determine cover code.

Table 2. Percent Cover Class Codes

Cover class	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5%
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

4) Record this information on the Meadow Vegetation Sampling Data Sheet. If a guild or cover is absent in the subplot, enter "0"

5) **Detailed cover determination guidance:**

- **Note**: The total of all percentages for every guild or ground cover may add up to more than 100% because different guilds may be in distinct layers.
- **Note**: See ocular clues to determining percent cover (Figure 5 below).
- **Note**: For help with graminoids vs. non-graminoids see guidance documents listed below, (f).

a. **Estimate <u>bare soil</u> cover.** This is the bare soil you can see plus any bare soil that is overtopped by litter, dead (dead, yet attached, plants killed by herbicide) or senescing (senesced, yet attached, vegetation present en masse in early spring if MU has not been burned, plowed, or flooded), and NOT underlain with green vegetation. If there is a significant duff layer (partially decomposed biomass below the litter), include this in bare soil on the data sheet.

b. **Estimate <u>open water</u>** using the cover classes. Record open water only if it is likely this condition is not a very short-term effect such as from recent rainfall.

c. **<u>RCG</u> percent cover** that is less than 1%, should be recorded as cover class 1. Any other non-RCG cover with less than 1% cover should be recorded as "0".

d. **<u>RCG dd</u>** is the RCG cover that is noted to be dead or dying due to herbicide treatment.

e. **<u>RCG sn</u>** is the RCG senescing naturally, not dead or dying.

f. Estimate **<u>native perennial</u>** cover percent as with all other guilds. Then with this guild only, determine if graminoids (true grasses, *Poaceae*) dominate or if non-graminoids dominate on your subplot. Indicate:
   - "**G**" for graminoid (true grass) dominance
   - "**N**" for non-graminoid (sedge, rush, native forbs) dominance.
   - This information is important for action recommendations as native graminoids are susceptible to fusilade application while non-graminoids are not as susceptible. For help with graminoids vs. non-graminoids See Graminoid vs. Non-graminoid Guidance on page 25 and the "Master Plant List with Guilds" provided in the digital Excel file.

g. Estimate cover percentages for **<u>remaining guilds</u>** and enter corresponding codes on data sheet.

h. **<u>Moist soil</u>** is a combination of native annual/biennials, introduced annual/biennials and bare soil. As with other cover assessments, "open water" is considered as a layer of cover that can overtop other guilds. Example: a plot with 50% cover bare ground that is topped by 25% open water, moist soil cover would be 50%.

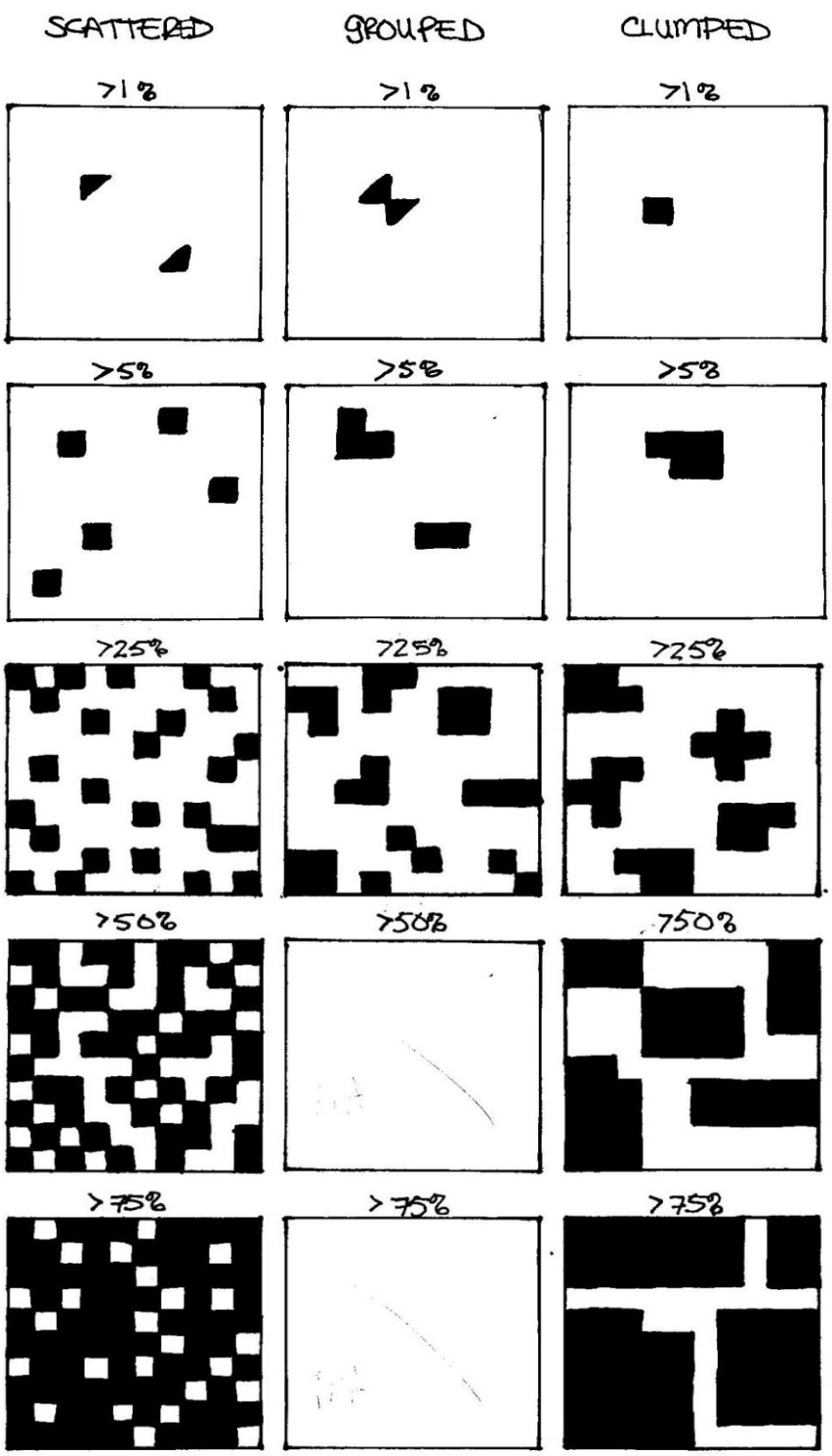


Figure 5. Ocular Clues to Percent Cover. Ocular clues sheet to help calibrate your estimation of percent cover in different distributions. Print this sheet and tape it to the inside of the recorders' clipboard for easy access.

Meadow Vegetation Sampling Data Sheet (first page)

Plot Label (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Plot Herbicide Treatment_____

Plot Herbicide Treatment Codes:

Code	Herbicide Treatment
T	Plot **T**reated
M	Plot **M**issed accidentally
A	Plot **A**voided (intentionally not treated)
PM	Plot **P**artly **M**issed accidentally
PA	Plot **P**artly **A**voided (intentionally not treated)
F	Plot **F**looded, not treated

RCG Stem Density (take data in Spring and Fall)

Sub-plot letter	**A**	**D**	**I**	**L**
Stem density code				

RCG stem density cover codes

Code	stems/m2	Code	stems/m2
1	0	6	201-500
2	1-10	7	501-1000
3	11-50	8	1001-2000
4	51-100	9	>2000
5	101-200		

Record Cover Guilds (take data in fall only)

Record cover code for each sub-plot below:

Plant or Cover Guild	**A**	**D**	**I**	**L**
Bare soil				
Open water				
RCG lv				
RCG dd				
RCG sn				
Native annual/biennial (N-A/B)				
Introduced annual/biennial (I-A/B)				
Native perennial (N-P)				
Native perennial plant type dominance: Enter **G** or **N** **G** = graminoid (true grass); **N** = non-graminoid				
Introduced perennial (I-P)				
Native woody (all heights)				
Introduced woody (all heights)				
Moist soil (combined coverage of bare soil + N-A/B + I-A/B)				

Percent cover codes

Code	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5%
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

Page 2 - <u>OPTIONAL</u> Individual Species Meadow Veg Sampling Data Sheet

Subplot Letter (record cover class code for subplots A, D, I and L)												
Species	**A**	B	C	**D**	E	F	G	H	**I**	J	K	**L**

Long Term Forest Vegetation Sampling Protocol

Ecological Objectives: The experimental phase of the Reed Canary Grass Adaptive Management Project resulted in determination of key vegetation measurements needed to inform the RCGAM decision tool and to enable generation of management recommendations. Key measurements are RCG stem density, predominance of native or non-native herbaceous cover and woody species size classes. Data must be collected with the same methodology and lack of bias during each sampling event.

Goal: To obtain a measure of RCG stem density, native wet meadow herbaceous species dominance and woody seedlings/saplings species and size at each vegetation sampling point within a forest management unit.

Personnel: Vegetation sampling may be performed with one or two people.

Timing:
1. Spring (when RCG is greening up—likely April or May): RCG stem density counts
2. August (during peak biomass, likely mid-August): RCG stem density counts and guild vegetation data
Note: timing should be interpreted with respect to phenologic delay and local adjustments due to climate—more southerly locations may need to take vegetation sampling data earlier.

Equipment: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with subplot location (flags, string, etc.), GPS unit if needed and one data sheet for each sampling point (see Forest vegetation sampling data sheet).

- **Note**: If there are no trees and no RCG but other vegetation, this Decision Tool to support management on RCG invaded lands may not be needed.

- **Note**: Or, if there is native vegetation, such as a wet meadow, a forest tool may not be needed. An unexpected outcome of glyphosate treatments to forest management units was the establishment of high quality meadow vegetation. To facilitate recognition of this kind of outcome by the decision tool, we must keep track of native wet meadow herbaceous cover to give users the option of changing their objective (managing for wet meadow instead of managing for forest). Monitoring for this trigger will be as follows: if the plot has greater than 50% native herbaceous cover observers will mark yes; if native herbaceous cover is less than 50% observers will mark no. This is recorded on every plot. If the plot is >50% native herbaceous another tool may be considered, such as the wet meadow tool.

Each time you sample a plot, please:

- **Record plot location on data sheet:**

  1) For each vegetation sampling plot, label Forest vegetation sampling data sheet with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number (refer to New Forest Vegetation Sampling Plots protocol). Record this plot label on the Forest Vegetation sampling data sheet.

  2) Note herbicide treatment code for each plot (see data sheet for code explanation and the Recording Herbicide Treatment History guidance document page 28).

- **Locate subplots to be sampled:**

    1) RCG stem density is sampled in the five white 1m x 1m subplots, one in each corner of the large 8 m x 8 m plot and one located near the center.

    2) At fall sampling the entire 8m x 8m plot is sampled for open water, RCG in three life stages and predominance of native herbaceous cover.

    3) At fall sampling the nested 4 m x 4 m plot is sampled for tree seedling and sapling measurements.

Variable	Plot size
Vegetation cover	8m x 8m
Seedling/sapling tally	4m x 4m
RCG stem density	1m x 1m

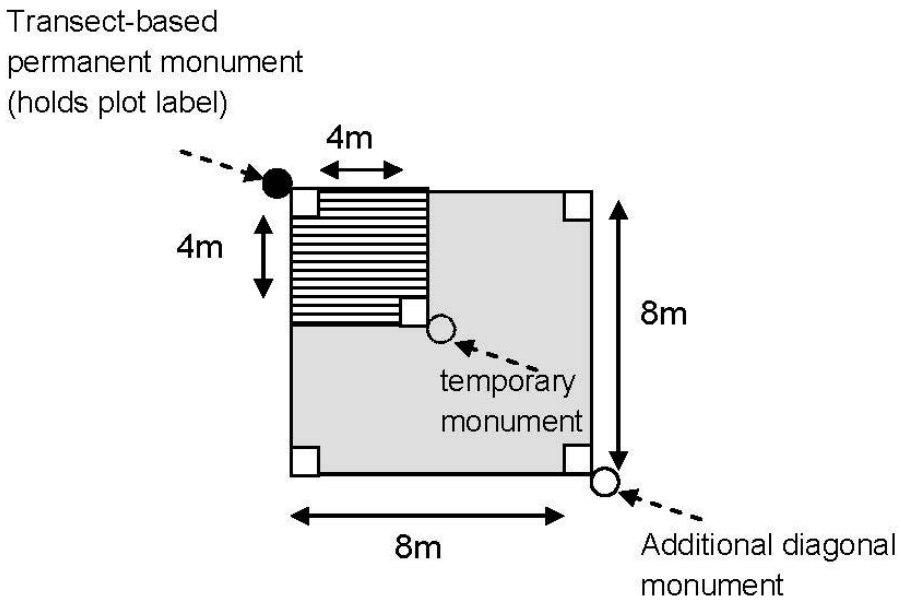


Figure 6. Vegetation monitoring plot specifications for the Forest Experiment. Herbaceous vegetation is sampled across the entire 8m x8m plot. Seedling/sapling measurements are taken in the striped zone. RCG stem density is measured in the 1m x1m white zones only.

<u>Spring and Fall RCG Stem Density Sampling</u> (1m x1m subplots):

This protocol is required during the spring (pre-treatment) vegetation sampling and the fall (maximum bio-mass) vegetation sampling. **Stem density is the only protocol required in the Spring**.

1) Estimate stem density of RCG (rhizome-based shoots and seedlings) in the four corners (1 m x 1 m) of the 8 m x 8 m plot, as well as the center of the 8 m x 8 m plot (this is also the opposite corner of the 4 m x 4 m plot; see Figure 7 above).
    - Stems are shoots that are green or shoots that have begun to senesce in late season. Both should be counted as stems. Observe RCG stem density in each 1m x 1m subplot.

2) Record stem density codes (see Table 1 below) on your plot data sheet for each of the five subplots.

Table 1 RCG Stem Density Category Codes

Code	Stem density (stems/m^2)	Code	Stem density (stems/m^2)
1	0	6	201-500
2	1-10	7	501-1000
3	11-50	8	1001-2000
4	51-100	9	>2000
5	101-200		

<u>Late Season (Fall) Only Vegetation Sampling</u> (8m x 8m plots):

This protocol is to be used as well as the Stem Density protocol, above, during fall vegetation sampling. (If optional species level data collection is desired please refer to <u>OPTIONAL</u> Species Level Sampling Protocols and data sheets on pages 37-50.)

1) Sampling is to be conducted in each of the 8m x8m vegetation sampling plots identified during plot layout (refer to New Forest Vegetation Sampling Plots protocol).

2) Vegetation guilds and ground cover types to be determined:
    a) Open water
    b) RCG lv
    c) RCG dd
    d) RCG sn

3) For open water over 1% aerial cover and for each RCG life stage, estimate the percent of the plot occupied. Use Table 2 below to determine cover code.

Table 2 Percent Cover class codes

Cover class	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5%
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

4) Native Herbaceous Cover Greater than 50% native? Mark "Y" (yes) or "N" (no).

5) Record this information on the Forest vegetation sampling data sheet. If a guild or cover is absent in the plot, enter "0"

6) **Detailed cover determination guidance:**

- **Note**: The total of all percentages for the RCG life stages and open water may be greater than 100% because they may be in distinct layers that are measured separately.
- **Note**: Refer to "ocular clues", Figure 5, above, to help determining percent cover.

a. **Estimate <u>open water</u>** using the cover classes. Record open water only if it is likely this condition is not a very short-term effect such as recent rainfall. Open water with less than 1% cover should be recorded as "0".

b. **<u>RCG</u> percent cover** that is less than 1% should be recorded as cover class 1.

c. **<u>RCG dd</u>** is the RCG cover that is noted to be dead or dying due to herbicide treatment.

d. **<u>RCG sn</u>** is the late season RCG that is senescing naturally, not dead or dying.

e. **<u>Native Herbaceous Cover</u>** greater than 50%? If the plot has greater than 50% native herbaceous cover mark yes; if native herbaceous cover is less than 50% mark no. This is recorded on every plot. If the plot is >50% native herbaceous another tool may be considered, such as the wet meadow tool.

<u>Fall Only Woody Species Sampling</u> (4m x 4m nested plot):

1) In the small nested 4 m x 4 m plot (see figure 6 above), monument the opposite corner temporarily to outline the 4 m x 4 m plot, creating a border to help with visualization.

2) Within this plot, record species (i.e. *Genus species*) for all woody seedlings and saplings (do not record dead stems) within the plot.

3) Tally the number of each species in each height category using the table below:

Table 3. Woody Height Categories:

Height (cm)
< 10 cm
11-50
51-100
101-200
>200

4) Record this information on the Forest vegetation sampling data sheet.

Forest Vegetation Sampling Data Sheet (first page)

Plot Label (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Plot Herbicide Treatment_____

Plot Herbicide Treatment Codes:

Code	Herbicide Treatment
T	Plot **T**reated
M	Plot **M**issed accidentally
A	Plot **A**voided (intentionally not treated)
PM	Plot **P**artly **M**issed accidentally
PA	Plot **P**artly **A**voided (intentionally not treated)
F	Plot **F**looded, not treated

Spring & Fall: RCG stem density; 1m x 1m sub-plots

Replicate (replicate locations are described as they are seen with observer facing the baseline, or forest edge)	Stem density class
1 (1m x1m, upper left corner)	
2 (1m x1m, upper right corner)	
3 (1m x1m, center)	
4 (1m x1m, lower left corner)	
5 (1m x1m, lower right corner)	

RCG stem density class categories:

Code	Stem density (stems/m^2)
1	0
2	1-10
3	11-50
4	51-100
5	101-200
6	201-500
7	501-1000
8	1001-2000
9	>2000

Fall Only: Record Cover Guilds Below; 8m x 8m plot

Cover Guild	**Cover code**
RCG lv	
RCG dd	
RCG sn	
Native Herbaceous cover greater than 50%- **Enter: Y** = yes or **N** =no	

Cover Class Codes

Code	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5% (RCG only)
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

Forest Vegetation sampling data sheet (second page)

Plot Label: (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Fall Only: Seedling/sapling measurements (4m x 4m subplot)

	Heights (cm) (tally individuals under each category with hatch marks, then record and circle the final tally)				
SPECIES	<10 cm	11-50	51-100	101-200	>200
For example: *Exampleis treeis*	|||| (4)		|| (2)		

RCGAM Meadow Vegetation Data Sampling Cheat Sheet

Revised 6/26/2012

Timing: **SPRING**, pretreatment (likely April/May) and **FALL**, during peak biomass (likely mid-August).
Equipment: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with subplot location (flags, string, etc.), one data sheet for each sampling plot (see Meadow vegetation sampling data sheet), and Master Plant List with Guilds for reference during fall sampling.

The Management Unit Monumenting and Data Collection Protocol has detailed instructions and additional guidance. See the Long Term Meadow Vegetation Sampling Protocol.

SPRING, at each plot take RCG Stem Density only:

1. Add additional temporary monuments (string, flags, etc.) to assist with subplot location.
2. Record the plot label on the Meadow vegetation sampling data sheet. Use official 6 letter label for the MU and plot number (e.g. RWB-NAM-10).
3. Note herbicide treatment code for each plot. See Meadow Vegetation Sampling Data Sheet for treatment code explanation and the "Recording Herbicide Treatment History" guidance page 28.
4. Place the $1m^2$ frame in the "upper left" corner of the vegetation sampling plot marking the corner of the plot, and framing subplot A. Note: Plots are divided into 12 subplots. Only subplots A, D, I, and L will be sampled (see protocol for subplot layout page 10).
5. Estimate RCG stem density (rhizome-based shoots and seedlings). Use density class categories listed on the data sheet.

FALL, at each plot: **Follow steps 1 through 5 above including estimate of RCG stem density.**

6. Estimate cover class for each plant or ground cover guild over 1% **cover** (All guilds except RCG with less than 1% cover are entered as "0"). Note: Use your **'**Master list' with guilds to determine species guild (life history and introduced status) to estimate cover categories, or "guilds". Guilds covers are listed on the data sheet:
    - Bare soil
    - Open water
    - RCG lv
    - RCG dd
    - RCG sn
    - Native Annual/Biennial (N-A/B)
    - Introduced Annual/Biennial (I-A/B)
    - Native Perennial (N-P)
    - Introduced Perennial, including RCG (I-P)
    - Native Woody
    - Introduced Woody
    - Moist soil (Combined coverage of bare soil and native A/B and introduced A/B)
7. Record dominance for Native Perennial guild of graminoids vs non-graminoids. For each subplot enter
    - "G" for graminoid dominance of native perennials or
    - "N" for non-graminoid dominance of native perennials
8. Collect vegetation cover data in subplots A, D, I, and L, If a guild is **absent** in subplots, indicate that the guild is absent by recording a "0".

For **optional** veg species data collection please refer to OPTIONAL Species Level Sampling Protocols and data sheets on pages 37-50.

RCGAM Forest Vegetation Data Sampling Cheat Sheet

Revised 6/26/2012

Timing: **SPRING**, pretreatment (likely April/May) and **FALL**, during peak biomass (likely mid-August).

Equipment: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with small nested plot and stem density replicate location (flags, string, etc.), one data sheet for each sampling plot (see Forest vegetation sampling data sheet), comprehensive species list with guilds for fall sampling plant guild determination.

The Management Unit Monumenting and Data collection Protocol and Long Term Forest Vegetation Sampling Protocol have more detailed instructions and guidance.

SPRING, at each plot:

1. **Add additional temporary monuments** (string, flags, etc.) to assist with stem density replicate locations.
2. **Record the transect number and plot letter** on the Forest veg sampling data sheet. Use official 6 letter label for the MU and the plot number. Ex: LCD-RSF-3A
3. **Note herbicide treatment code** for each plot (see data sheet for treatment code explanation and ""Recording Herbicide Treatment History" guidance", page 28).
4. **Estimate RCG stem density** (rhizome-based shoots and seedlings) in the four corners (1 m x 1 m) of the 8 m x 8 m plot, as well as the center of the 8 m x 8 m plot. Use the density class categories listed on the data sheet.

FALL, at each plot:

1. Follow steps 1 through 4 above including estimate of RCG stem density.
2. In the large plot (8 m x 8 m) Determine percent cover for the following vegetation and ground cover types:

    a. Open water
    b. RCG lv
    c. RCG dd
    d. RCG sn

3. Record if native herbaceous cover is greater than 50 %. If so enter "Y" for yes. If less than 50% enter "N" for no.
4. Woody seedlings and saplings**:** In the small nested 4 m x 4 m plot, monument the opposite corner temporarily to outline the 4 m x 4 m plot, creating a border to help with visualization. Within this plot, record genus and species (do not record dead stems) within the plot and tally their heights using the categories listed on the data sheet.

Continue taking vegetation cover data for each plot in the MU.
For **optional** veg species and woody species data collection please refer to OPTIONAL Species Level Sampling Protocols and data sheets on page 37-50.

GRAMINOID vs. NON-GRAMINOID GUIDANCE

For your "native perennial" guild only we are asking that you determine if graminoids (true grasses) dominate or if non-graminoids dominate on your subplots. You will estimate cover percent of native perennials as with all other guilds then indicate "G" for graminoid dominance or "N" for non-graminoid dominance. This information is important for action recommendations as native graminoids would be susceptible to fusilade application while non-graminoids would not. The main ingredient in Fusilade is fluazifop-p-butyl, which is a lipid synthesis inhibitor. The chemical is taken up via the phloem and is hydrolyzed to fluazifop acid. The acid accumulates in meristems and inhibits acetyl CoA carboxylase (ACCase). ACCase catalyzes early stages of fatty acid synthesis, but fluazifop acid prevents this causing cell membranes to fail. The cells then burst, leak, or die. In grasses, ACCase is more susceptible to the fluazifop acid or grasses just metabolize the acid more efficiently than non-grasses. The following information will help you to distinguish true grasses from "look-alike" sedges and rushes.

Use Table 6 and Figure 13 to help assist in distinguishing true grasses from sedges and rushes.

1) Record which plant type dominates in the Native Perennial Cover Guild

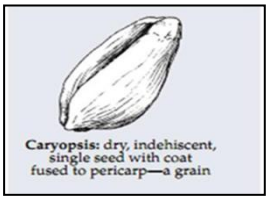
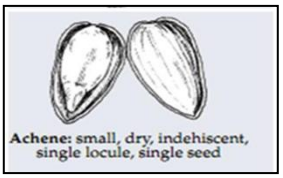
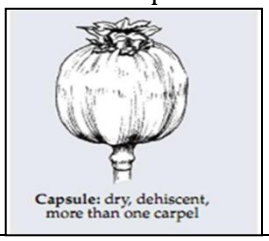
2) Indicate "G" for graminoid (true grasses) and "N" for non-graminoid (sedges, rushes, forbs)

These references were used in developing this document.

Monaco TJ, SC Weller, FM Ashton. 2002. Weed Science: principles and practices. John Wiley & Sons, Inc, NY. (page 314)

CL. Porter. 1967. Taxonomy of Flowering Plants (second edition). W. H. Freeman and Company, San Francisco. 472 pp.

Table 4. Information to assist in distinguishing true grass from sedges and rushes. Rushes and sedges will be included in the non-graminoid category along with forbs. This information is needed for action recommendations. Like RCG, native graminoids are sensitive to fusilade, *"a selective post emergence herbicide for control of annual and perennial grass (graminoid) weeds".*

	Habitat	Stems	Leaves	Seed
Poaceae True grasses Graminoid (G)	Drier, some aquatic	Jointed Hollow internodes Circular	2-ranked Always present Sheath open	Caryopsis (grain) 
Cyperaceae Sedges non-graminoid (N)	Usually wet	Not jointed, solid, triangular "Sedges have edges"	3-ranked when present, sheath closed	Achene 
Juncaceae Rushes non-graminoid (N)	Usually wet	Not jointed, hollow, cylindrical "Rushes are round"	In basal tuft, blades cylindrical to flat	3-valved capsule 

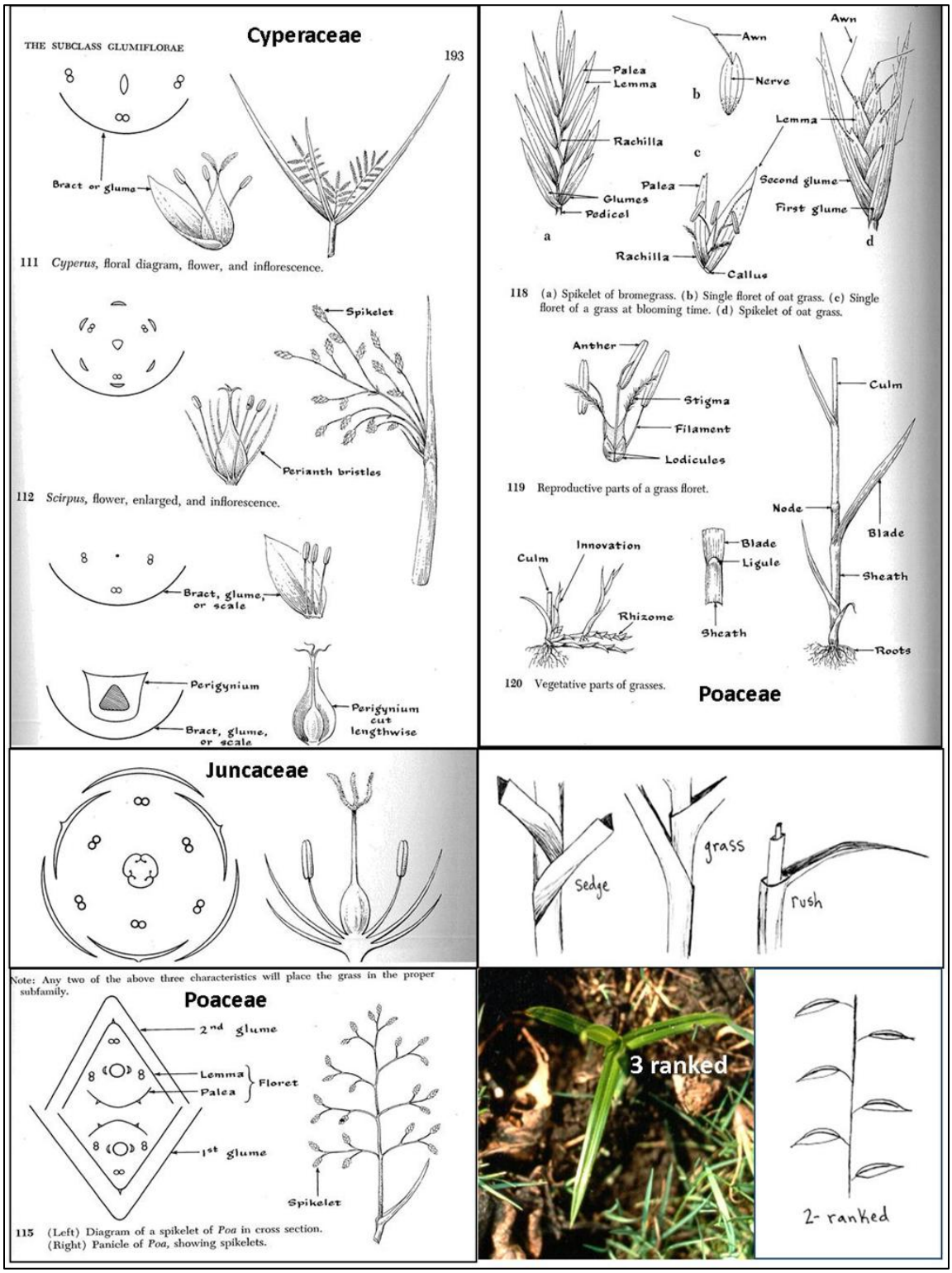


Figure 7 Morphological and anatomical characteristics of grasses, sedges, and rushes.

RECORDING PLOT HERBICIDE HISTORY

Plots with Missed or Avoided Herbicide Treatment

Following this guidance will allow us to track management units in which *plots have **not** been treated uniformly*.

Affected areas include:

1. Spots accidentally missed due to operator error or equipment problems
2. Areas of desirable vegetation intentionally avoided during herbicide application

Missed or avoided plots will be reported on the first data collection following the known or detected herbicide lapse.

Note:

a) Fusilade missed is likely observable during fall veg data collection of the same year.

b) Glyphosate missed is likely observable during spring veg data collection of the following year.

Table 5. The top portion of all vegetation data collection sheets asks you to record one of these codes:

Code	Herbicide Treatment
T	Plot **T**reated
M	Plot **M**issed accidentally
A	Plot **A**voided (intentionally not treated)
PM	Plot **P**artly **M**issed accidentally
PA	Plot **P**artly **A**voided (intentionally not treated)
F	Plot **F**looded, not treated

Please record to the best of your knowledge what action or condition has most recently affected the vegetation on each sampled subplot (A, D, I and L) and on your plots.

TREATMENT IMPLEMENTATION

FOREST BROADCAST SEEDING PROTOCOL

Ecological Objective: To rapidly establish early successional species of floodplain forest trees in formerly RCG-dominated areas adjacent to intact forest floodplain
Goal: broadcast forest species seed in a properly prepared site
Personnel: Broadcast seeding is most efficiently accomplished with 2 people.
Timing: Seeding will occur in Spring/Summer 2010, with possible supplemental seeding in Fall 2010. Sliver maple must be both collected and sown early in the growing season, but for most species, seed can be stored until sown in fall.
Equipment: seed may be hand-broadcast or a contractor could broadcast seed with fertilizer spreader, where feasible and for the appropriate site conditions, a drag (section of chain link fence) may be pulled to maximize seed-to-soil contact for light seeded species.

Step 1: Selecting species composition and purchasing seed
Select at least four species (less if appropriate) of early successional woody species that are appropriate for your MU setting and elevation. In addition to your own knowledge of what species are appropriate for the MU, looking to the adjacent floodplain forest and other similar un-invaded forest sites will help provide a guide for species selection. For all management units, *Acer saccharinum* would be a good species to include. See Table 1 for species information.

> Note: The primary seeding event will likely occur in spring. If feasible, a fall seeding (in 2010) may enhance the chance of revegetation success. Plan for the potential to execute a fall seeding. This step is optional, but planning for it now will make it more likely that you will be prepared if the opportunity presents itself.

Acquire seed by purchasing a seed mix from a vendor, or use self-collected seed. If purchasing seed, order the seed from the vendor recommended in Table 2 (or another vendor with regional coordinator approval). Specify to the vendor that no species be substituted without your consent. Mark on the order "no substitutions without prior approval".

For advice on seeding and storage rates, see Table 1. Also consult with forester or vendor on storage and seeding rates, and share any important information via a "forest participants only" message on Basecamp

Step 2: Site preparation
To maximize the likelihood of establishment from the seed mix, prepare the site to achieve good seed-to-soil contact. A variety of tools may help achieve a good seed bed, including removal of thatch or RCG that is dead from glyphosate herbicide applications. Apply site preparation that is suitable for the site conditions, and consider the following guidance:

- Visually estimate percent cover of thatch prior to seeding, most likely in the spring.
    - For MUs with little thatch cover (25% or less, this situation may be a result of flood scour), no site preparation is necessary.
    - For MUs with significant thatch cover (enough to carry a burn), do a fall or spring burn prior to seeding (fall grazing may substitute where applicable if needed). If a fall burn cannot be applied, hay or mow in the fall.

    - If RCG emerges from the seed bank in spring/early summer immediately prior to seeding, apply glyphosate to pre-perenniating RCG seedlings before broadcasting seed.
- Avoid disking and other treatments that disturb soil (though a persistent RCG rhizome mat is of concern, disturbing the soil will trigger RCG and other weed germination and potential growth from RCG dormant buds).
    - High RCG seed bank densities existed at all study sites prior to control efforts, and though this density is likely reduced by treatments, it is unlikely that it has been reduced below threshold levels (seed bank reduction data)
    - Disking is only appropriate if it is performed in combination with herbicide application. Disking alone will trigger RCG growth from dormant buds.
- Record all site preparation activities on Basecamp via the "09/10 Seeding and Site Prep for MUs" file.

Step 3: Broadcast seed

- Do a broadcast seeding (do not drill).
- Timing: Seed can be broadcast in spring/early summer following the last major flood event.
- Seed should be uniformly distributed to ensure an even seeding rate across the management unit.
- Follow these sound seeding practices:
    - Use filler (fine grain play sand or other appropriate material) to achieve even broadcast of seed.
    - Use appropriate equipment to broadcast seed evenly over large areas. If this is not possible, spreading seed by hand is the next best option.
    - Lighter seed (virtually all early successional species) can be dragged in lightly after broadcast.
    - Avoid seeding on a windy day or immediately prior to an anticipated severe flooding event.

Step 4: Follow-up weed control

Controlling grass and weed competition around establishing seedlings will probably be critical. Follow up weed control may be spot-spraying with glyphosate in the early spring/early summer (immediately after RCG germinates and before it perenniates) or, to control grass species only, broadcast spraying with Fusilade (Fusilade does not damage trees). We will work together to determine more specific direction on follow-up control after revegetation efforts have begun.

Table 6. Early successional woody species and associated collection time, storage, and seeding rate.[1]

Species	Collection[2]	storage	Seeding rate per acre
Acer saccharinum (Silver maple)	June	plant ASAP	¼ to ½ bushels
Acer negundo (Box elder)	October to December	Retains viability better if stored in heated room than cooled cellar	No established rates
Betula nigra (River birch)	June-August	Germination is best with unstratified seed	No established rates
Fraxinus pennsylvanica (Green ash)	October to January	Keep dry, stored in feed sacks in 40F cooler for several weeks; can be seeded as holdover from previous year's collection in the spring	1-2 bushels
Fraxinus nigra (Black ash)	October to December	Keep dry, stored in feed sacks in 40F cooler for several weeks; can be seeded as holdover from previous year's collection in the spring	1-2 bushels
Ulmus americana (Elm)	June	Can be planted immediately or stored cool	No established rates
Populus deltoides (Cottonwood)	April/May	plant ASAP	No established rates
Salix exigua (Sandbar willow)	April/May	plant ASAP	No established rates
Salix nigra (Black willow)	April/May	plant ASAP	No established rates

[1] Adapted from DNR pamphlet http://www.dnr.state.mn.us/treecare/maintenance/collectingseed2.html and Silvics of North America http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm.

[2] Seed trap data may inform collection dates for our locations; for individual locations see Seed Trap Slideshow from the March 1, 2010 coordination meeting posted on Basecamp.

Table 7. Potential vendors and associated notes. As more information becomes available, post notes to Basecamp and we will modify this document over time to reflect information participants gather.

Vendor	Notes
Jon Alness (jonalnesszvf@msn.com) Zumbro Valley Forestry 4120 County Road 21 NE Elgin, MN 55932 (507) 280-4267	Vendor considered by the Corps (via Kurt Brownell), also Vendor for MN DNR (via Craig VanSickle at the Bedora Nursery). Don't get many requests for Silver maple, cottonwood, ash, etc. Accepts orders year 'round.
Terry Purtillo (Iowa) 515-490-3852	Vendor for MN DNR (via Craig VanSickle at the Bedora Nursery). May be able to provide Silver maple, River birch. Good for Iowa, central Iowa and East of Davenport.
Mike Hamilton (Iowa) 319-378-0537, cell: 319-573-0615	Vendor for MN DNR (via Craig VanSickle at the Bedora Nursery)
One-Stop Forestry 101 East Greene Postville, IA 52162 (319) 864-3586	Vendor considered by the Corps (via Kurt Brownell)
DuWayne Oakes, Oakes Forestry PO Box 697 Spring Grove, MN 55974 (507) 498-5814	Vendor considered by the Corps (via Kurt Brownell) Notes from 2010 research by Eric Nelson: Green Ash: $55/bushel (80,000 to 100,000 seeds per bushel). Harvest Oct 1, 2010. Has some on hand right now (25 bushel). Can seed 2010 seeds in spring of 2011. Silver Maple: $35/bushel (about 15,000 seeds per bushel). Harvest about May 25, 2010. River birch: $55/pound (note by pound) 170,000 seeds per pound. Harvest end of May 2010.
Winterhaven Enterprises 62529 187th Street Janesville, MN 56048 (507) 234-3564	Vendor considered by the Corps (via Kurt Brownell)
Sundance Silviculture PO Box 16538 Duluth, MN 55816 (218) 723-1511	Vendor considered by the Corps (via Kurt Brownell)
Dave Page RR 2, Box 494 Hammond, MN 55991 (507) 753-2559	Vendor considered by the Corps (via Kurt Brownell)
Cascade Forestry Service 21995 Fillmore Road Cascade, IA 52033 (563) 852-3042	Vendor considered by the Corps (via Kurt Brownell)
James Enblom 141 1st Street Hammond, MN 55991 (507) 753-2573	Vendor considered by the Corps (via Kurt Brownell)
Mike Graham, Graham Environmental Services, Inc. S1095 Westland Dr. Spring Valley, WI 54767 (715) 778-5730	Vendor considered by the Corps (via Kurt Brownell)
Bob Petrzelka, Geode Forestry PO Box 86 Swedesburg, IA 52652 (319) 254-2232	Vendor considered by the Corps (via Kurt Brownell)

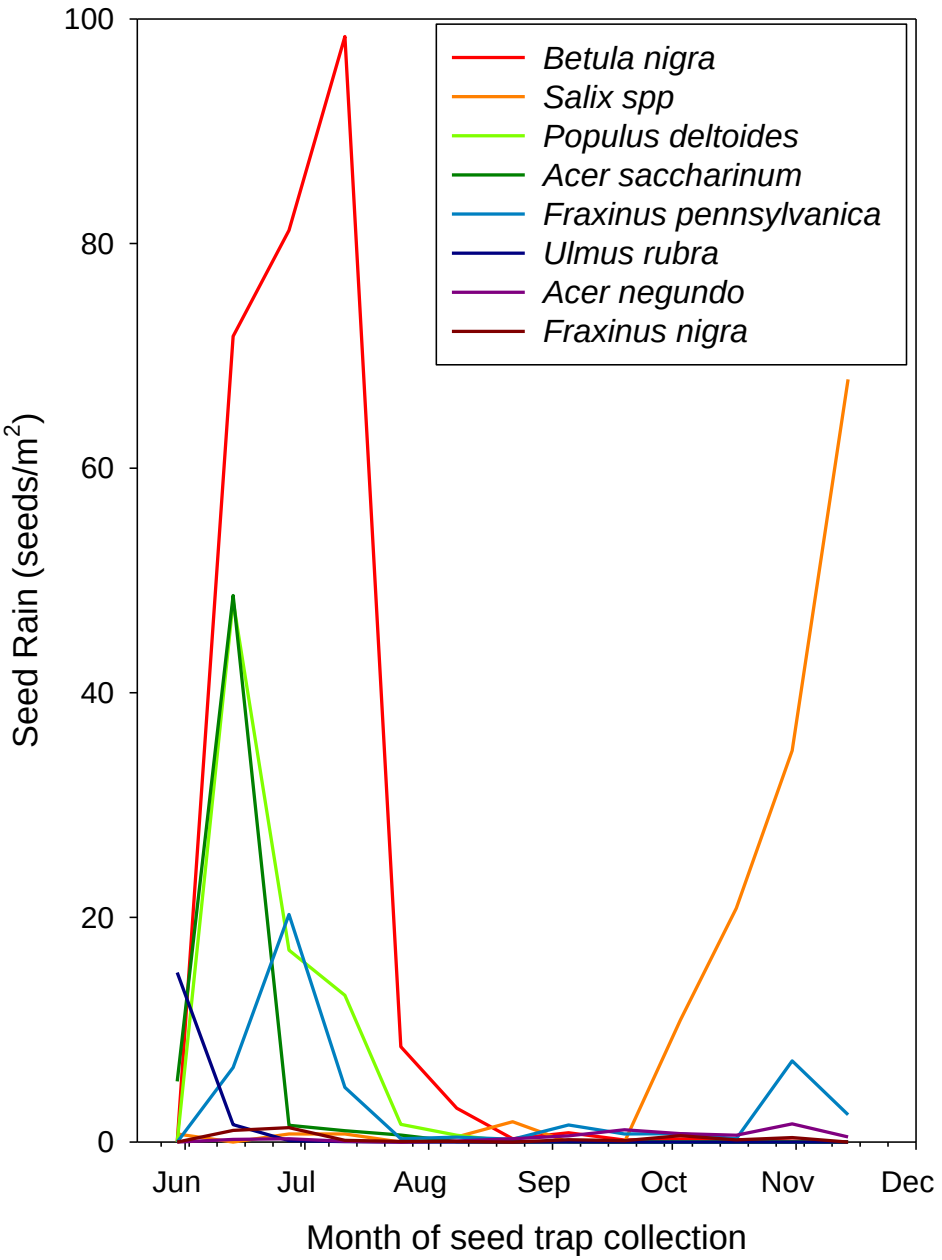


Figure 13. Mean seed rain density for averaged across all RCGAM forest MUs. This information was determined from seed trap samples collected in the 2008 growing season.

MEADOW BROADCAST SEEDING PROTOCOL

Ecological Objective: To rapidly establish wet meadow species in formerly RCG-dominated areas following primary RCG control treatments.
Goal: To broadcast a diverse, pre-stratified wet meadow seed at a competitive seeding rate in a properly prepared site.
Timing: Acquire seed, store seed, and do site preparation during the growing season prior to seed sow. Broadcast seed in either late fall/winter (dormant) or spring.
Equipment: Wet meadow seed, refrigerator, filler sand, manure spreader

1. Acquire and store seed (see RCGAM Meadow Seed Purchase and Storage Protocol)

2. Prepare the site to achieve good seed-to-soil contact: To maximize the likelihood of establishment from the seed mix, prepare the site to achieve good seed-to-soil contact. A variety of tools may help achieve a good seed bed, including removal of thatch or RCG that is dead from glyphosate herbicide applications. Apply site preparation that is suitable for the site conditions, and consider the following guidance:

- Note: this protocol assumes that RCG control (usually primary treatment in the form of at least two years of fall glyphosate applications) precedes seeding efforts after which belowground RCG rhizome mortality should be considerable [*after both one and two years of appropriately-timed (August-September) glyphosate applications, RCG recolonization was exclusively from seeds and no rhizomes (Adams and Galatowitsch 2006)*]. We will monitor both success of seeding efforts and corresponding RCG seed bank density to determine a threshold RCG seed bank density that limits native establishment from seed.
- Visually estimate percent cover of thatch prior to seeding, most likely in the spring.
    - For MUs with little thatch cover (25% or less; this situation may be a result of flood scour), no site preparation is necessary.
    - For MUs with significant thatch cover (enough to carry a burn), do a fall or spring burn prior to seeding (fall grazing may substitute where applicable if needed). If a fall burn cannot be applied, hay or mow in the fall.
    - If RCG emerges from the seed bank in spring/early summer immediately prior to seeding, apply glyphosate to pre-perenniating RCG seedlings before broadcasting seed.
- Avoid disking and other treatments that disturb soil (though a persistent RCG rhizome mat is of concern, disturbing the soil will trigger RCG and other weed germination and potential growth from RCG dormant buds).
    - High RCG seed bank densities existed at all study sites prior to control efforts, and though this density is likely reduced by treatments, it is unlikely that it has been reduced below threshold levels (seedbank reduction data)
    - Disking is only appropriate if it is perfomed in combination with herbicide application. Disking alone will trigger RCG growth from dormant buds.

3. Broadcast seed

- Do a broadcast seeding (do not drill). Seed can be broadcast either in fall/winter (dormant seeding—seed may be broadcast into snow or before snowfall) or in spring. Seed should be uniformly distributed to ensure an even seeding rate across the management unit.
- Follow these sound seeding practices:
    - Use a manure spreader to broadcast seed evenly over large areas. Examples include Vicon spreader, which has an agitator and arm to mimic hand broadcasting, and the E-ZEE flow fertilizer spreader which is wheel driven and drops the seed. If this is not possible, using a hand spreader is the next best option.
    - Filler sand (fine grain play sand) may be needed to achieve even broadcast of seed, especially for small areas that are hand seeded.
    - If hand-seeding, it may make sense to flag off smaller sub-units and divide seed accordingly to ensure even broadcast rates across the management unit.
    - Following seed broadcast, soil can be packed with a cultipacker to press the soil in against the seeds.
    - Avoid seeding on a windy day or immediately prior to an anticipated severe flooding event.
    - Seeding over frozen ground and fresh snow may work well. Seed can be observed in equipment tracks in the snow, ensuring even seeding. Also there is less opportunity for equipment to get stuck while the ground is frozen, and seeds may sink into the snow, avoiding potential wind drift.
    - For more tips, see a reputable resource for your region, e.g. for Region 6:
        http://www.prairieplains.org/assets/files/restoration_manual_1.pdf
        http://www.prairieplains.org/assets/files/restoration_manual_2.pdf

Note: If a MU was planted as a dormant seeding, and severe flooding removed seed from the MU, plan to reseed when possible.

HERBICIDE APPLICATION TABLE

Follow guidance below for implementing herbicide treatments (also serves to provide details for PUP and herbicide contracts).

	Fluazifop (fusillade)	**Glyphosate**		
Herbicide	**FusiladeDX** (grass-specific, active ingredient: fluazifop)	**RoundupPro** (broad spectrum, active ingredient: glyphosate)	**Rodeo** (broad spectrum, active ingredient: glyphosate)	**Aquamaster** (broad spectrum, active ingredient: glyphosate)
Application rate (all label-approved rates)	24 oz/A for later stages of growth	6 pts/A	4.5 pts/A	4.5 pts/A
Additive	LI-700 non-ionic surfactant (as a penetrant, also used in place of crop oil concentrate): 0.5% by volume	None required	LI-700 non-ionic surfactant (used as a penetrant) Rate: 0.005 % vol: vol ratio or 5 L of LI700/1000 L spray mixture	LI-700 non-ionic surfactant(used as a penetrant) Rate: 0.005 % vol: vol ratio or 5 L of LI700/1000 L spray mixture
Timing	Apply prior to anthesis, when RCG is 10-18 inches tall (May/June) OR, If RCG is greater than 18" tall or anthesis (seed head formation) has begun, first mow or hay, then apply 24 oz/A when RCG regrowth is 6-10"	Mid-August: when RCG carbohydrate flux to rhizomes is at a maximum, prior to major RCG senescence (adjusting for phenology)	Mid-August: when RCG carbohydrate flux to rhizomes is at a maximum, prior to major RCG senescence (adjusting for phenology)	Mid-August: when RCG carbohydrate flux to rhizomes is at a maximum, prior to major RCG senescence (adjusting for phenology)
Description of management units to which herbicide is typically applied	Wet meadow sites (nearly RCG or nearly meadow) Forest sites after revegetation efforts	nearly RCG wet meadow sites Forest sites prior to revegetation efforts	nearly RCG wet meadow sites Forest sites prior to revegetation efforts	nearly RCG wet meadow sites Forest sites prior to revegetation efforts
Aquatic use	Do not apply directly to water or to areas where surface water is present Rainfast in 1 hr	Do not apply directly to water, to areas where surface water is present	Approved for aquatic use	Approved for aquatic use

OPTIONAL Species Level Sampling Protocols

Long Term Meadow Species Level Vegetation Sampling Protocol

Ecological Objectives: The experimental phase of the Reed Canary Grass Adaptive Management Project resulted in determination of key vegetation measurements needed to inform the RCGAM decision tool and to enable generation of management recommendations. Key measurements prior to and after treatment are RCG stem density and percent cover for vegetation and cover guilds. Individual plant species cover data may be optionally collected as well. Data must be collected with the same methodology and lack of bias during each sampling event.
Goal: To obtain a measure of RCG stem density and the percents of vegetative cover and ground cover guilds and vegetation species from particular vegetation sampling plots within a meadow management unit.
Personnel: Vegetation sampling may be performed with one or two people.
Timing: Pretreatment (when RCG is greening up—likely April or May), and annually during peak biomass (likely mid-August). This timing should be interpreted with respect to phenologic delay and local adjustments due to climate—more southerly locations may need to take vegetation sampling data earlier.
Equipment: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with subplot location (flags, string, etc.), GPS unit if needed and one data sheet for each sampling point (see Meadow vegetation sampling data sheet).

Stem density and cover guild sampling is to be conducted in each of the vegetation sampling plots identified during plot layout (refer to New Meadow Vegetation Sampling Plots protocol).

Each time you sample a plot please:

- **Record plot location on data sheet:**

3) For each vegetation sampling plot, label Meadow vegetation sampling data sheet with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number (refer to New Meadow Vegetation Sampling Plots protocol for plot numbering scheme). Record this plot label on the Species Level Meadow vegetation sampling data sheet.

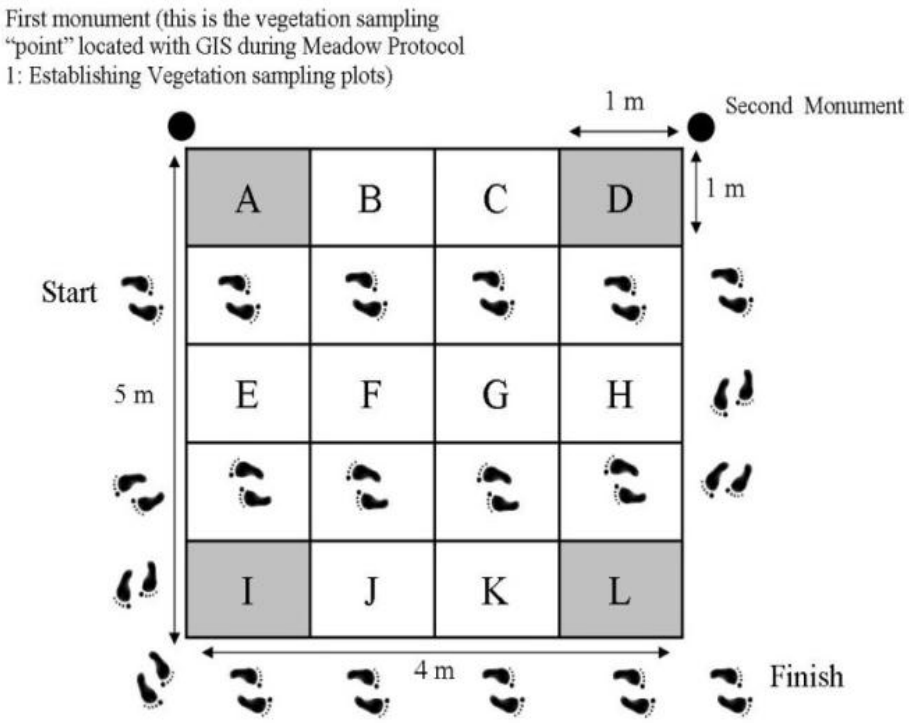
4) Note herbicide treatment code for each plot (see data sheet for code explanation and Recording Plot Herbicide History guidance document on page 27.)

- **Locate subplots to be sampled:**

3) Place the 1m x 1m frame in the "upper left" corner of the vegetation sampling plot marking the corner of the plot, and framing sub-plot A (see Figure 4 below). Avoid trampling the vegetation in the sub-plots to be sampled. If vegetation is very tall, it may be necessary to remove one side of the frame and reconnect the frame around the vegetation.

4) The same subplots, A, D, I, and L, will be used for stem density and for fall cover guild and plant species sampling. Subplot labeling will remain consistent with the labeling used during the experimental phase when all lettered subplots were sampled (see Figure 4 below).

Figure 4 Sub-plot Sampling Diagram



<u>Spring and Fall RCG Stem Density Sampling</u>:

This protocol is required during the spring (pre-treatment) vegetation sampling and the fall (maximum bio-mass) vegetation sampling. **RCG stem density is the only protocol required in the Spring**.

3) Estimate stem density of RCG (rhizome-based shoots AND seedlings) in 1m x 1m sub-plots A, D, I, and L (see Figure 4 above).
    - Stems are shoots that are green or shoots that have begun to senesce in late season. Both should be counted as stems. Observe RCG stem density in each shaded 1m x 1m subplot.

4) Record stem density codes (see Table 1 below) on your plot data sheet for each of the four subplots.
   Table 1: RCG Stem Density Category Codes:

Code	Stem density (stems/m^2)
1	0
2	1-10
3	11-50
4	51-100
5	101-200
6	201-500
7	501-1000
8	1001-2000
9	>2001

Fall Only Vegetation Cover Guild Sampling with optional veg species level data collection:

This protocol is to be used as well as the Stem Density protocol, above, during fall vegetation sampling. The same sub-plots, A, D, I, and L (see Figure 4 above), used for stem density will be sampled to determine cover codes for vegetation guilds and ground cover type and optional individual vegetation species.

6) You should bring the "Master Plant List with Guilds" document with you into the field for reference during fall data collection. During previous project years a comprehensive species list was created. Species life history and introduced vs native status ("**guild**") was determined. This information is used to estimate cover categories during fall sampling. The "Master Plant List with Guilds" is provided in a digital Excel file labeled: Master Plant List with Guild form. It contains all commonly encountered plants with current name spelling, form (**graminoid vs non-graminoid**), and **guild**. Unknown plants or plants encountered that do not appear on the Master Plant List can be checked on the USDA Plants Database, http://plants.usda.gov/.

7) Vegetation guilds and ground cover types and species to be determined
    m) Bare soil
    n) Open water
    o) RCG lv
    p) RCG dd
    q) RCG sn
    r) Native perennials (does *not* included RCG); You will indicate dominance in this guild:
        - "**G**" for graminoid (true native grass) dominance or
        - "**N**" for non-graminoid (sedge, rush, native forbs) dominance.
    s) Introduced perennials (*does* include RCG)
    t) Native annuals/biennials (herbaceous species)
    u) Introduced annuals/biennials (herbaceous species)
    v) Native woody species (shrubs and trees of any height)
    w) Introduced woody species (shrubs and trees of any height)
    x) Moist soil, not a true "guild", but a composite cover category including:
        - native annuals/biennials
        - introduced annuals/biennials
        - bare soil (see step 5a below)
    y) Individual vegetation species

8) For each cover type or plant guild or plant species over 1% aerial cover, estimate the fraction of the sub-plot occupied by the cover. Use table 2 below to determine cover code.

Table 2: Percent Cover Class Codes

Cover class	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5%
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

9) Record this information on the Meadow vegetation sampling data sheet. If a guild or cover is absent in the subplot, enter "0". If a plant species is recorded in one subplot but is absent in other plots record a "0" for the other subplots.

10) **Detailed cover determination guidance:**

- **Note**: The total of all percentages for every guild or ground cover may add up to more than 100% because different guilds may be in distinct layers.
- **Note**: See ocular clues to determining percent cover (Figure 5 below).
- **Note**: For help with graminoids vs non-graminoids (5f below) see Figure 6 below.

a. **Estimate <u>bare soil</u> cover.** This is the bare soil you can see plus any bare soil that is overtopped by litter, dead (dead, yet attached, plants killed by herbicide) or senescing (senesced, yet attached, vegetation present en masse in early spring if MU has not been burned, plowed, or flooded), and NOT underlain with green vegetation. If there is a significant duff layer (partially decomposed biomass below the litter), include this in bare soil on the data sheet.

b. **Estimate <u>open water</u>** using the cover classes. Record open water only if it is likely this condition is not a very short-term effect such as from recent rainfall.

c. **<u>RCG</u> percent cover** that is less than 1% should be recorded as cover class 1. Any other non-RCG cover with less than 1% cover should be recorded as "0".

d. **<u>RCG dd</u>** is the RCG cover that is noted to be dead or dying due to herbicide treatment.

e. **<u>RCG sn</u>** is the RCG senescing naturally, not dead or dying.

f. Estimate **<u>native perennial</u>** cover percent as with all other guilds. Then with this guild only, determine if graminoids (true grasses, poacea) dominate or if non-graminoids dominate on your sub-plot. Indicate:
   - "**G**" for graminoid (true grass) dominance or
   - "**N**" for non-graminoid (sedge, rush, native forbs) dominance.
   - This information is important for action recommendations as native graminoids are susceptible to fusilade application while non-graminoids would not be. See Graminoid vs Non-graminoid Guidance document and the Master Plant List with Guilds in a digital Excel file labeled: Master Plant List with Guild form.

g. Estimate cover percentages for **<u>remaining guilds</u>** and enter corresponding codes on data sheet.

h. **<u>Moist soil</u>** is a combination of native annual/biennials, introduced annual/biennials and bare soil. As with other cover assessments, "open water" is considered as a layer of cover that can overtop other guilds.
   Example: a plot with 50% cover bare ground that is topped by 25% open water, moist soil cover would be 50%.

i. For each **plant species over 1% cover**, identify each plant species (scientific name, i.e. *Genus species*). Estimate the fraction of area that is covered by each species (aerial cover) using the percent cover classes.
    a. Unknown species: When species identification is uncertain, give tentative species identification, followed by "cf", rather than only listing species to "sp". Uncertain species should be collected and vouchered when diagnostic traits (generally flowers or fruits) are present.
    b. If there is significant cover of a species that is dead or senescing (but not yet detached litter), record those observations in a separate row.
        i. Vegetation should be recorded as senescing (sn) when more than 50% of stem and leaf tissues on stems are not green (so yellow). If the plant is 100% yellow (just dying, not killed by herbicide) mark as senescing (sn).
        ii. If the vegetation is 50-100% tan-brown (killed by herbicide), mark as dead (dd).
        iii. If a species occurs as both live, and dead or senescing, be sure to mark live percent cover as live (lv).
        iv. In summary, use the following life stage codes: lv- live, sn-senescing, dd-dead.

Examples:

Species	Cover class
Panicum virgatum – lv	5
Panicum virgatum -- dd	2

Species Level Meadow Vegetation Sampling Data Sheet (first page)

Plot Label (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Plot Herbicide Treatment_____

Plot HerbicideTreatment Codes:

Code	Herbicide Treatment
T	Plot **T**reated
M	Plot **M**issed accidentally
A	Plot **A**voided (intentionally not treated)
PM	Plot **P**artly **M**issed accidentally
PA	Plot **P**artly **A**voided (intentionally not treated)
F	Plot **F**looded, not treated

Spring and Fall RCG Stem Density

Subplot letter	**A**	**D**	**I**	**L**
Stem density code				

RCG stem density cover codes

Code	stems/m2	Code	stems/m2
1	0	6	201-500
2	1-10	7	501-1000
3	11-50	8	1001-2000
4	51-100	9	
5	101-200		

Fall Only Record Cover Guilds Record cover code for each sub-plot below:

Plant or Cover Guild	**A**	**D**	**I**	**L**
Bare soil				
Open water				
RCG lv				
RCG dd				
RCG sn				
Native annual/biennial (N-A/B)				
Introduced annual/biennial (I-A/B)				
Native perennial (N-P)				
Native perennial plant type dominance: Enter **G** or **N;** **G** = graminoid (true grass); **N** = non-graminoid				
Introduced perennial (I-P)				
Native woody (all heights)				
Introduced woody (all heights)				
Moist soil (combined coverage of bare soil + N-A/B + I-A/B)				

Percent cover codes

Code	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5% (RCG only)
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

Page 2 - OPTIONAL Individual Species Meadow Veg Sampling Data Sheet

Plot Letter (record cover class code for subplot A, D, I and L)												
Species	**A**	B	C	**D**	E	F	G	H	**I**	J	K	**L**

<u>OPTIONAL</u> Species Level Sampling Protocol

Long Term Forest Species Level Vegetation Sampling Protocol

<u>Ecological Objectives</u>: The experimental phase of the Reed Canary Grass Adaptive Management Project resulted in determination of key vegetation measurements needed to inform the RCGAM decision tool and to enable generation of management recommendations. Key measurements are RCG stem density, predominance of native or non-native herbaceous cover and woody species size classes. Individual plant species cover data may be optionally collected as well. Data must be collected with the same methodology and lack of bias during each sampling event.
<u>Goal</u>: To obtain a measure of RCG stem density, native wet meadow herbaceous species dominance and woody seedlings/saplings species and size at each vegetation sampling point within a forest management unit.
<u>Personnel</u>: Vegetation sampling may be performed with one or two people.
<u>Timing</u>: Pretreatment (when RCG is greening up—likely April or May), and annually during peak biomass (likely mid-August). This timing should be interpreted with respect to phenologic delay and local adjustments due to climate—more southerly locations may need to take vegetation sampling data earlier.
<u>Equipment</u>: 1m x 1m PVC frame, metric measuring tape, additional temporary monumenting supplies to assist with subplot location (flags, string, etc.), GPS unit if needed and one data sheet for each sampling point (see Forest vegetation sampling data sheet).

- **Note**: If there are no trees and no RCG but other vegetation, this Decision Tool to support management on RCG invaded lands may not be needed.

- **Note**: Or, if there is native vegetation, such as a wet meadow, a forest tool may not be needed. An unexpected outcome of glyphosate treatments to forest management units was the establishment of high quality meadow vegetation. To facilitate recognition of this kind of outcome by the decision tool, we must keep track of native wet meadow herbaceous cover to give users the option of changing their objective (managing for wet meadow instead of managing for forest). Monitoring for this trigger will be as follows: if the plot has greater than 50% native herbaceous cover observers will mark yes; if native herbaceous cover is less than 50% observers will mark no. This is recorded on every plot. If the plot is >50% native herbaceous another tool may be considered, such as the wet meadow tool.

<u>Each time you sample a plot, please</u>:

- **Record plot location on data sheet:**

    1) For each vegetation sampling plot, label Forest vegetation sampling data sheet with refuge code (three letters), then a dash, then management unit name code (three letters), and plot number (refer to New Forest Vegetations Sampling Plots protocol). Record this plot label on the Forest Vegetation sampling data sheet.

2) Note herbicide treatment code for each plot (see data sheet for code explanation and the "Recording Plot Herbicide History" guidance document, page 27).

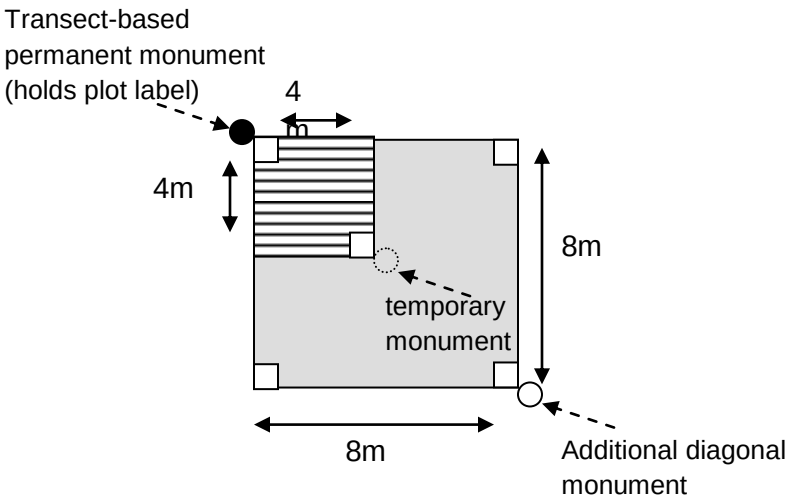
- **Locate subplots to be sampled:**
  1) RCG stem density is sampled in the five white 1m x 1m subplots, one in each corner of the large 8 m x 8 m plot and one located near the center.

  2) At fall sampling the entire 8m x 8m plot is sampled for open water, RCG in three life stages and predominance of native herbaceous cover and cover data for all species above 5% cover.

  3) At fall sampling the striped nested 4 m x 4 m plot is sampled for tree seedling and sapling measurements.

Figure 6 Forest Plot Orientation and Layout

Variable	Plot size
Vegetation cover	8m x 8m
Seedling/sapling tally	4m x 4m
RCG stem density	1m x 1m



Spring and Fall RCG Stem Density Sampling (1m x1m subplots):

This protocol is required during the spring (pre-treatment) vegetation sampling and the fall (maximum bio-mass) vegetation sampling. **Stem density is the only protocol required in the Spring**.

3) Estimate stem density of RCG (rhizome-based shoots and seedlings) in the four corner subplots (1 m x 1 m) of the 8 m x 8 m plot, as well as the center subplot of the 8 m x 8 m plot (this is also the opposite corner of the 4 m x 4 m plot; see Figure 6 above).
    - Stems are shoots that are green or shoots that have begun to senesce in late season. Both should be counted as stems. Observe RCG stem density in each 1m x 1m sub-plot.

4) Record stem density codes (see Table 1 below) on your plot data sheet for each of the five subplots.

Table 1. RCG Stem Density Category Codes

Code	Stem density (stems/m^2)	Code	Stem density (stems/m^2)
1	0	6	201-500
2	1-10	7	501-1000
3	11-50	8	1001-2000
4	51-100	9	>2000
5	101-200		

Fall Only Vegetation Sampling (8m x 8m plots):

This protocol is to be used as well as the Stem Density protocol above during fall vegetation sampling.

1) Sampling is to be conducted in each of the 8m x8m vegetation sampling plots identified during plot layout (refer to New Forest Vegetation Sampling Plots protocol).

2) Vegetation guilds and ground cover types to be determined:
    e) Open water
    f) RCG lv
    g) RCG dd
    h) RCG sn
    i) Individual plant species cover greater than 5%

3) For open water over 1% aerial cover and for each RCG life stage, and for plant species > 5% estimate the percent of the plot occupied. Use table 2 below to determine cover code.

Table 2: Percent Cover class codes

Cover class	Percent cover
0	0 or not present
1	<1% (RCG cover only)
2	1-5%
3	>5-25%
4	>25-50%
5	>50-75%
6	>75-100%

4) Native Herbaceous Cover Greater than 50% native? Mark "Y" (yes) or "N" (no).

5) Record this information on the Forest vegetation sampling data sheet. If a guild or cover is absent in the plot, enter "0"

6) **Detailed cover determination guidance:**

- **Note**: The total of all percentages for the RCG life stages and open water may be greater than 100% because they may be in distinct layers that are measured separately.
- **Note**: Refer to "ocular clues", Figure 5, above, to help determining percent cover.

f. **Estimate <u>open water</u>** using the cover classes. Record open water only if it is likely this condition is not a very short-term effect such as recent rainfall. Open water with less than 1% cover should be recorded as "0".

g. **<u>RCG</u> percent cover** that is less than 1% should be recorded as cover class 1.

h. **<u>RCG dd</u>** is the RCG cover that is noted to be dead or dying due to herbicide treatment.

i. **<u>RCG sn</u>** is the late season RCG that is senescing naturally, not dead or dying.

j. **<u>Native Herbaceous Cover</u>** greater than 50%? If the plot has greater than 50% native herbaceous cover mark yes; if native herbaceous cover is less than 50% mark no. This is recorded on every plot. If the plot is >50% native herbaceous another tool may be considered, such as the wet meadow tool.

i. For each **<u>plant species over 5% cover</u>**, identify each plant species (scientific name, i.e. *Genus species*). Estimate the fraction of area that is covered by each species (aerial cover) using the percent cover classes.

v. Unknown species: When species identification is uncertain, give a tentative species identification, followed by "cf", rather than only listing species to "sp". Uncertain species should be collected and vouchered when diagnostic traits (generally flowers or fruits) are present.

vi. If there is significant cover of a species that is dead or senescing (but not yet detached litter), record those observations in a separate row.

1. Vegetation should be recorded as senescing (sn) when more than 50% of stem and leaf tissues on stems are not green (so yellow). If the plant is 100% yellow (just dying, not killed by herbicide) mark as senescing (sn).
2. If the vegetation is 50-100% tan-brown (killed by herbicide), mark as dead (dd).
3. If a species occurs as both live, and dead or senescing, be sure to mark live percent cover as live (lv).
4. In summary, use the following life stage codes: lv- live, sn-senescing, dd-dead.

Example:

<u>Species</u>	<u>Cover class</u>
Panicum virgatum – lv	5
Panicum virgatum - dd	2

<u>Fall Only Woody Species Sampling</u> (4m x 4m nested plot):

5) In the small nested 4 m x 4 m plot (see figure 6 above), monument the opposite corner temporarily to outline the 4 m x 4 m plot, creating a border to help with visualization.

6) Within this plot, record species (i.e. *Genus species*) for all woody seedlings and saplings (do not record dead stems) within the plot.

7) Tally the number of each species in each height category using the table below:

Table 3. Woody Height Categories:

Height (cm)
< 10 cm
11-50
51-100
101-200
>200

8) Record this information on the Forest vegetation sampling data sheet.

Species Level Forest Vegetation Sampling Data Sheet (first page)

Plot Label (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Plot Herbicide Treatment_____

Plot Herbicide Treatment Codes:

Code	Herbicide Treatment
T	Plot **T**reated
M	Plot **M**issed accidentally
A	Plot **A**voided (intentionally not treated)
PM	Plot **P**artly **M**issed accidentally
PA	Plot **P**artly **A**voided (intentionally not treated)
F	Plot **F**looded, not treated

Spring & Fall: RCG stem density; 1m x 1m sub-plots

RCG stem density class categories:

Replicate (replicate locations are described as they are seen with observer facing the baseline, or forest edge)	Stem density class
1 (1m x1m, upper left corner)	
2 (1m x1m, upper right corner)	
3 (1m x1m, center)	
4 (1m x1m, lower left corner)	
5 (1m x1m, lower right corner)	

Code	Stem density (stems/m^2)
1	0
2	1-10
3	11-50
4	51-100
5	101-200
6	201-500
7	501-1000
8	1001-2000
9	>2000

Cover (8mx8m plot)

Fall Only: Record Cover Guilds Below; 8m x 8m plot

Cover Class Code

Cover Guild	Cover code
RCG lv	
RCG dd	
RCG sn	
Native Herbaceous cover greater than 50%- **Enter: Y** = yes or **N** =no	
Individual Species Cover	
1.	
2.	
3.	
4.	
5.	
6.	
7.	

Code	Percent cover
0	0 or not present
1	<1% (RCG only)
2	1-5% (RCG only)
3	>5-25%
4	>25-50%
5	>50-75%

Forest Vegetation sampling data sheet (second page)

Plot Label: (refuge code, management unit code, plot number)_____

Names of Investigators_____Date_____

Fall Only: Seedling/sapling measurements (4m x 4m subplot)

	Heights (cm) (tally individuals under each category with hatch marks, then record and circle the final tally)				
SPECIES	<10 cm	11-50	51-100	101-200	>200
For example: *Exampleis treeis*	|||| (4)		|| (2)		